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13. *Citation.*—References may be placed in a list at the end of an article or arranged as footnotes. The former method is preferable in long papers. In the list references are best arranged alphabetically, reference in the text being made by writing after the author's name, as it occurs the year of publication of the work, adding, if necessary, a page number and enclosing these in parentheses, thus: "Benham (1915, p. 176).' Example of forms of citation for alphabetical list:—

BENHAM, W. B., 1915. Oligochaeta from the Kermadec Islands, *Trans. N.Z. Inst.*, vol. 47, pp. 174–85.

PARK, J., 1910. *The Geology of New Zealand*, Christchurch, Whitcombe and Tombs.

When references are not in alphabetical order the initials of the author should precede the surname, and the year of publication should be placed at the end.

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TRANSACTIONS

AND

PROCEEDINGS

OF THE

NEW ZEALAND INSTITUTE

FOR THE YEAR 1917

VOL. L

(New Issue)

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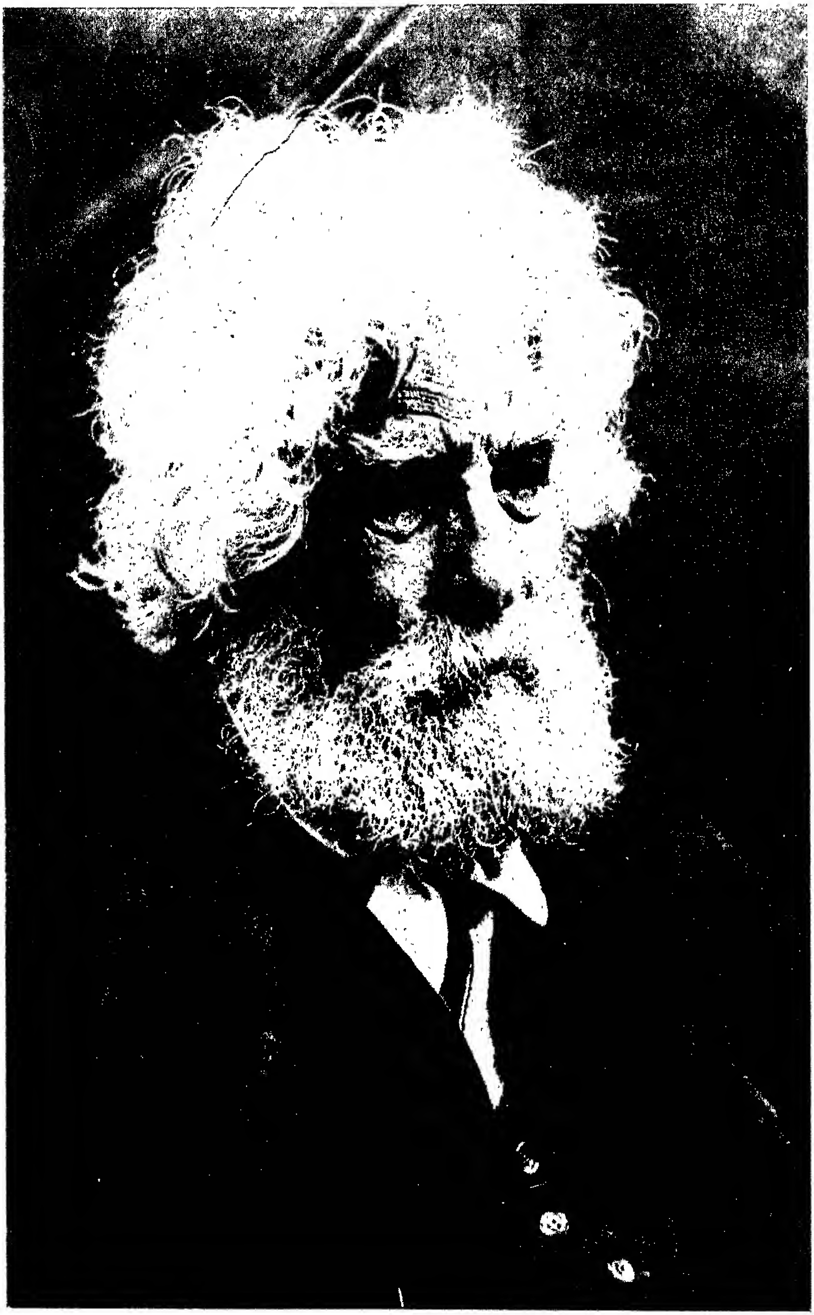
ERRATA.

Page 64, line 5: *For* Hypolepsis *read* Hypolepis.
Plate VI, fig. 1: This figure should be inverted.



ALEXANDER McKAY.

[*Frontispiece.*

OBITUARY.

ALEXANDER McKAY.

Alexander McKay was born at Carsphairn, in Kirkcudbrightshire, Scotland, in 1842, and was educated as part-time scholar at the village school. He came to New Zealand in 1863, landing at the Bluff from the ship "Helenslee," and for some time he followed the occupation of a gold-miner, both in Otago and at Wakamarino, after which he went to Australia and worked on the New South Wales and Queensland diggings. In 1866 he returned to New Zealand, and for the next four years was engaged in exploring and prospecting the south-west part of the Mackenzie country, conducting his explorations alone and at all seasons of the year. It was during this period that he first became acquainted with Dr. (afterwards Sir Julius) von Haast, then Provincial Geologist for Canterbury. Later, in 1870, while engaged in prospecting for coal at Ashley Gorge, he again met Dr. von Haast, who engaged him as an assistant in prosecuting some geological surveys which he was carrying out for the New Zealand Government. After exploring the central mountain regions of Canterbury and the Shag Point coalfield the party returned to Christchurch, and Mr. McKay was further employed to collect from the saurian beds of the Waipara River, North Canterbury, for the Canterbury Museum. In 1872 he carried out the excavation of the "Moa-bone Cave" at Sumner under Dr. Haast's directions. Towards the end of that year, Dr. (later Sir James) Hector, noting the fine saurian collections in the Canterbury Museum, engaged Mr. McKay to make a collection of similar remains from Amuri Bluff for the Colonial Museum and Geological Survey. On the conclusion of this work, in March, 1873, Mr. McKay came to Wellington, and shortly afterwards was appointed a permanent officer in the Geological Survey, remaining in this employment until the suspension of the Survey in 1893. After that date he held the appointment of Mining Geologist to the Mines Department, and subsequently of Government Geologist, until his retirement from the Public Service in 1906. He died at Kelburn on the 8th July, 1917.

The geological work carried out by the Survey under Sir James Hector did not include much mapping or detailed field-work, but consisted chiefly of geological reconnaissance and exploration of unknown localities, together with reports on individual mines or small mining districts. Mr. McKay was employed at first largely in fossil-collecting; but at a later date, as his colleagues Hutton, Cox, and Park dropped out of the Survey, the greater part of the exploration fell to his share. As a fossil-collector he had a keen eye, but he had rather too high an estimation of the power of a palaeontologist to reconstruct a whole specimen from fragments, and in consequence a considerable proportion of his collections are now being found to be of doubtful utility. It was unfortunate that his collections were not examined and described at once, for with his undoubtedly great aptitude for collecting, and his memory for species, he would have been quick to acquire that special knowledge which is essential to the finest work. His collections were apparently looked over by Sir James Hector,

and a few selected specimens were displayed in the Colonial Museum under their generic names, but the great bulk were stored away and have only recently been partially re-examined. Over 120,000 fossils were acquired by the Geological Survey under Sir James Hector, and of these a considerable majority were collected by Mr. McKay. This tangible result was considered by him his greatest achievement, but it is easily outweighed by his contributions to the field and structural geology of New Zealand.

During his geological explorations Mr. McKay covered almost the whole area of New Zealand, and in accordance with the practice then in vogue he prepared reports on all his travels. These papers, published in the *Reports of Geological Explorations*, still form the only source of information for many districts in New Zealand. In his later years he resumed many of his earlier observations in papers dealing with larger districts, such as Central Otago, Marlborough, and the West Coast. As a writer he was not always lucid, and seldom graceful in style; indeed, his earlier papers show that writing must have been a great labour to him. He was under the further disadvantage of not being able to give a simple descriptive account of what he observed, but of having to interpret it in terms of the official classification adopted by the Survey. Nevertheless he had the merit not to suppress any discordant observations, and it is easy for one familiar with the classification adopted to obtain from the reports a clear enough account of the geological sequence he observed. As a field geologist he was a reliable worker, and in districts regarding which controversies have arisen his account has generally stood the test of time.

During the last few years of the old Geological Survey, and subsequently during his employment by the Mines Department, Mr. McKay broke fresh ground in the domain of structural geology. In 1884–85 he traversed the Middle Clarence Valley, and in 1888–89 the Awatere Valley, in each of which there are long strips of Notocene rocks resting on one side of the valley unconformably on the older rocks, and bounded by long fault-lines on the other. On each side the old rocks rise into mountains of 6,000 ft. to 9,000 ft. The presence, in the Notocene series, of the Amuri limestone, a fine-grained chalky limestone containing little or no terrigenous sediment, led Mr. McKay to conclude that at the time of its formation the Kaikoura Mountains, as such, were not in existence. Since the Notocene series is structurally involved in the mountains, he concluded that the latter originated at a comparatively recent (post-Miocene) date. His subsequent work was devoted mainly to the extension of this theory of mountain-building by block-faulting (although he did not actually use these terms) throughout the rest of New Zealand, and notably in Central Otago. Although this work received little attention at the time, it is now accepted as substantially correct by the majority of New Zealand geologists, and it is greatly to Mr. McKay's credit that he originated the idea independently of any influence from other countries.

In his later years he devoted much attention to photography, and was very successful in obtaining photomicrographs of igneous rocks, and also long-distance views of the Tararua Mountains from his home in Kelburn.

J. A. T.

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TRANSACTIONS

OF THE

NEW ZEALAND INSTITUTE,

1917.

Art. I.—*The Prothallus and Young Plant of* Tmesipteris.

By the Rev. J. E. Holloway, D.Sc.

[*Received by Editors, 31st December, 1917; issued separately, 24th May, 1918.*]

Plates I–III.

It has been mainly, perhaps, owing to the fact that the various members of the Psilotaceae are confined to tropical and subtropical regions, and to the temperate countries of the Southern Hemisphere, that our knowledge of the gametophyte and of the embryogeny of the sporophyte of this interesting group of plants has increased so slowly. This order has been the last to yield information with regard to the early stages in the life-history of its members, and so to furnish evidence which may help us to form reasonable theories concerning its genetic relationships. The genus *Tmesipteris*, for example, is confined to Australia, New Zealand, and certain Pacific islands, and hence has remained for the most part beyond the reach of European and American botanists.

With regard to not a few of the chief pteridophytic groups, not only has the number of those who have searched for the prothallus been limited, but the search itself has been rendered difficult on account of the fact that the gametophyte is often subterranean, and also that although the adult plants are not as a rule rare in their occurrence, yet their abundance in any particular locality is often due largely to their powers of vegetative reproduction, for the germination of the spores seems only to take place in localities where the conditions are peculiarly favourable, and where also the prothallus and young plant will remain quite undisturbed during the protracted period of their development. However, it seems to be evident from the writings of most of those who have given an account of the details of their search for pteridophytic prothalli that when once one can learn from experience in the field to recognize the localities favourable to the development of the particular kind of prothallus searched for there is no obstacle other than the necessity

for patience in dissecting to hinder its being collected in comparative abundance.*

There is no doubt that the wet temperate climate of that part of New Zealand subject to the excessive western rainfall is especially favourable to pteridophytic growth and to the sexual reproduction of the plants. In the present paper I propose to give an account of my search for and discovery of the prothalli and young plants of *Tmesipteris* in the neighbourhood of Hokitika, in the Province of Westland, New Zealand, and to describe the form, structure, and development of the prothallus and sexual organs and of the young plant, and also to trace some of the early stages in the development of the embryo. Two writers have published certain results obtained by them in their search for the gametophyte of the Psilotaceae. Lang (1904) has given a description of a single prothallus which he has provisionally referred to *Psilotum*. This prothallus is certainly a puzzle, for on the one hand the finding-place strongly suggests that it belongs to *Psilotum*, but on the other its form and structure differ very widely from what I propose to describe for *Tmesipteris*, and from what Professor A. A. Lawson, of Sydney University, has already described. Lawson (1917A) gives a preliminary account of the prothallus of *Tmesipteris* based upon several specimens obtained by him from different localities in eastern Australia. This account was published early in 1917, but came into my hands only at the end of the year, when my own paper was almost completed. No reference to it, therefore, will be found in the body of the present paper, but in the concluding section I have compared in detail my own results with his, and noted our points of agreement or otherwise. There is a considerable literature dealing with the anatomy and morphology of the adult plant in the Psilotaceae. The more recent of those writings, such as those of Scott (1909), Bower (1908), Seward (1910), Thomas (1902), Boodle (1904), Ford (1904), and Sykes (1908), have brought together a weighty body of evidence for relating the Psilotaceae with the fossil *Sphenophyllales*. In my comparative remarks I have endeavoured to consider the results obtained from the study of the prothallus and young plant of *Tmesipteris* with regard to the systematic position to be assigned to *Tmesipteris* and *Psilotum*.

As on other occasions, I desire to acknowledge the special debt of gratitude I am under to Dr. L. Cockayne, F.R.S., for his constant encouragement and advice, and also to Professor C. Chilton, M.A., D.Sc., for his kindness in giving me free access to the Botanical Laboratory at Canterbury College.

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* The following may be cited in this connection: H. Bruchmann, *Über die Prothallien und die Keimpflanzen mehrerer europäischer Lycopodien*, pp. 4 and 5, 1898; D. H. Campbell, *The Eusporangiatae* (the adult gametophyte of *Ophioglossum moluccanum* and *O. pendulum*), pp. 11 and 13, 1911; M. Treub, "Some Words on the Life-history of Lycopods" (tropical species), *Ann. of Bot.*, vol. 1, pp. 119–23, 1887; J. E. Holloway, "Studies in the New Zealand Species of the Genus *Lycopodium*, Part I," *Trans. N.Z. Inst.*, vol. 48, pp. 259–63, 1916. In the last-mentioned paper I described the discovery of three species of *Lycopodium* prothalli of the *L. cernuum* type, one epiphytic species of the *L. Phlegmaria* type, and three subterranean species of the *L. complanatum* and *L. clavatum* types, the three latter being found in abundance. Since writing this paper I have found the prothalli of the three epiphytic varieties of *Lycopodium* which occur in New Zealand, in the case of two of them in great abundance, and have also continued to come across sporeling plants and prothalli of the three subterranean species in many different localities, and in large numbers.

Tmesipteris tannensis (lanceolata) growing in humus along trunk of fallen tree, Stewart Island forest. (Photograph.)

OCCURRENCE AND HABIT.

Tmesipteris occurs commonly throughout New Zealand as an epiphyte on the stems of tree-ferns and other forest-trees. The much-branched brown rhizome penetrates through the mass of aerial rootlets which densely clothes the stem of the tree-fern, and especially is to be found underneath the decurrent stipites of its fronds. Certain of the rhizome-branches turn upwards, and emerge as green aerial shoots, bearing scattered scale leaves below and above the full-sized leaves of characteristic form and the sporophylls.

There is a certain amount of variation noticeable in the habit and general form of the plant, which is probably to be put in connection with the nature of the surface on which it grows. However, it must be noted that some writers have recognized distinct varieties. For example, when growing on certain species of the tree-fern *Cyathea* the whole plant is generally somewhat stunted in size, the rhizome being more scantily branched and the aerial shoots short and semi-erect. In these cases the surface of the tree-fern stem consists solely of the mat of black brittle aerial rootlets, the stipites of the fronds not reaching down the stem much below its crown, and consequently there being only the dense tough mat, of greater or lesser thickness, of the interlaced rootlets in which the *Tmesipteris* plants can grow. My experience has been the same probably as that of others who have tried to dissect out the plants from such intractable material. It is almost impossible to get the plant with all its various branchlets complete, and one gives up in despair the search for the young plants or for the prothallus.

In those parts of New Zealand, however, especially in the botanical districts, as defined by L. Cockayne,* which lie for the most part west of the Southern Alps, together with that ecologist's South Otago and Stewart Districts, where the average rainfall is very heavy, there is an extremely rich growth of Pteridophytes, and *Tmesipteris* occurs abundantly on the tree-fern *Dicksonia squarrosa* and on moss- or humus-covered forest-trees, and also in the heaps of humus which lie on the ground at the bases of the trees. Here the size and habit of the plant are markedly different from those described above. The penetrating rhizomes may be as much as 2 ft. or 3 ft., or even more, in total length, and are for the most part extensively branched; also, it is an easier matter to dissect out a plant entire from such a substratum. The aerial branches arising from a single plant are fairly numerous, and droop down 2 ft., 3 ft., and 4 ft. in length, the branches of groups of plants hanging like a fringe from some tree-branch or fallen tree-stem. In Plate I is shown a single plant with a much-branched rhizome and three aerial stems, the latter showing fertile regions.

I have found in the neighbourhood of Hokitika, Westland, in the low-lying forest which borders the sea-front, both young and mature plants of *Tmesipteris* growing on the stems of *Dicksonia squarrosa* in great abundance. On this particular tree-fern the frond-stipites run down the stem for some distance before they enter its surface, and hence in young individuals the greater part of the stem, and in older plants the upper portion, is covered with the adhering bases of the fronds. The young plants of *Tmesipteris* occur both immediately underlying the stipites and in the ridges of aerial rootlets which project outwards between them. During the month of September, 1917, I obtained several lengths of tree-

* *Trans. N.Z. Inst.*, vol. 49, p. 65, 1917.

fern stems which showed the presence of abundant young plants of *Tmesipteris*, and took them home for dissection. Between twenty and thirty prothalli were discovered on this occasion in all stages of development (except, of course, the very youngest), some of these prothalli bearing young plants in various stages of growth. During the following two months many other prothalli were obtained in the same way, the total number to date being between sixty and seventy, as well as many isolated prothallial plantlets, some of the latter being complete and others broken in process of dissection.

By reason of their brown colour and large size, the prothalli and the rhizomes of the young plants are clearly to be seen amidst the tangle of black aerial tree-fern rootlets. There is not much humus present, but the rhizoids of the prothalli and plantlets are closely intermixed with ramenta from the tree-fern. Prothalli and plantlets also of *Lycopodium Billardieri* var. *gracile* were found in abundance on these tree-ferns, and also the prothalli of various ferns and several liverworts. The spores of *Tmesipteris* germinate best on those parts of the tree-fern stems where the surface, owing to the presence of the frond-stipites, is more loose and open. The young plants, once established, will develop, and their rhizomes ramify in all directions, even after the bases of the fronds have completely fallen away and their places have been filled up by the mat of aerial rootlets; but the younger plantlets will only be found higher up the stem. It was noticed that in the groves of *Dicksonia squarrosa* in this particular locality many young tree-ferns of from 6 ft. to 8 ft. in height bore young developing plantlets of *Tmesipteris*, but that it was only on still taller stems that the mature plants were to be seen, whilst from those of 15 ft. or more in height the plants had generally disappeared altogether from the lower portions of the stem and were only to be found on the upper half. It would seem that *Tmesipteris* prefers a fairly loose substratum both for the germination of its spores and also for the full development of the plants.

That this is so becomes apparent when one observes the conditions under which it flourishes on Stewart Island and on those parts of the mainland (*e.g.*, Bluff Hill) which face Stewart Island across Foveaux Strait. In these localities *Tmesipteris* occurs very commonly in the masses of loose humus which are gathered at the bases of forest-trees and tree-ferns, and there the plant often reaches a most luxuriant development. Also, on such large branches and tree-trunks throughout the forest as are covered with humus, and especially on those which lie more or less horizontal, there is frequently a rich growth of the plant. In January, 1915, I made a visit to Stewart Island for the purpose of searching for the young plants and prothalli of *Tmesipteris*. This botanical district is well known to be exceptionally favourable for the growth of epiphytic ferns and lycopods, on account of its wet climate. There is one locality especially, bordering the shore of Preservation Inlet, near the upper reaches of its south-west arm, where there is a very characteristic and interesting type of forest. This has been described by L. Cockayne in his *Report on a Botanical Survey of Stewart Island* (Government Printer, Wellington, 1909). Cockayne speaks of this type of forest as "the Yellow-pine (*Dacrydium intermedium*) Association." This particular association is confined to wet ground, and the low forest consists mainly of the small pine which gives its name to the association, and of other conifers, as, for example, *Dacrydium biforme*, *Podocarpus Hallii*, and certain other species belonging to these two genera; while the floor of the forest is covered with curious

large globular cushions of mosses and liverworts (*e.g.*, *Dicranoloma Billardieri* and species of *Plagiochila*) from 1 ft. to 2 ft. or more in diameter, and with three species of *Lycopodium* (*L. volubile*, *L. scariosum*, and *L. varium*) growing in wonderful luxuriance. *Lycopodium varium* here grows in great clumps, which are as much as 6–8 ft. across. *Tmesipteris* and filmy ferns are also in great abundance—in fact, the general appearance of the vegetation is suggestive of a past age when Gymnosperms and Pteridophytes were dominant rather than Phanerogams. During my visit to Stewart Island I arranged an expedition to spend a few days in this locality, but owing to heavy rains and floods the party was isolated on the sea-coast and nearly met with disaster. However, on the last day I reached the spot, and during an hour's search succeeded in finding several young prothallial plantlets of *Tmesipteris* growing in thick loose humus on a fallen tree-trunk. There is no doubt that with longer time at his disposal a searcher would find the place a most favourable one for the discovery of both the young plants and the prothalli.

It was not till the spring of 1917 that the further discovery was made, in the neighbourhood of Hokitika, of both plantlets and prothalli of *Tmesipteris*, as recorded above. In the dissection of these specimens from the mass of aerial rootlets on the stems of the tree-ferns a certain amount of patience and care had to be used, for these rootlets are exceedingly tough and are closely intermatted, and both the prothalli and rhizomes of *Tmesipteris* are very brittle and easily broken. However, by pulling away the stipites of the tree-fern fronds and carefully tearing apart the mass of aerial rootlets the golden-yellow rhizomes and the brown prothalli were easily to be seen (by reason both of their characteristic colour and of their comparatively large size), and, the black aerial rootlets being cut away with dissecting scissors, they were readily obtained.

General Form and Structure of the Prothallus.

The prothallus-body is cylindrical in form, being radially constructed. It is brown in colour, and is covered with numerous long golden-yellow rhizoids. It never seems to reach the light, and is quite destitute of chlorophyll. The largest specimens found are shown in figs. 5, 6, and 8, being 18 mm. and 13 mm. respectively in total length, and the smallest in figs. 11 and 12, these being from 1 mm. to 2 mm. long. In its unbranched form the prothallus is carrot-shaped, tapering down gradually from a fairly thick head and upper region towards the basal first-formed end, which culminates in a more or less long-drawn-out point (figs. 1, 2, and 11). The first-formed basal region does not show such a marked primary tubercle as is so well known in the case of the prothalli of *Lycopodium cernuum* or in those of *Ophioglossum* and *Helminthostachys*, but there is commonly a succession of gentle swellings from the original point of growth upwards by which the prothallus grows in girth (figs. 1, 2, 11, and 13). The actual head is generally the stoutest region (figs. 12, 13, &c.), being sometimes curiously swollen, and the growing apex is bluntly rounded.

Sooner or later the head of the prothallus forks dichotomously, and one of the branches so formed may later fork again. In some cases the first branching is postponed till after the prothallus has attained a length of as much as 8–10 mm. (figs. 1, 2), and the result is the carrot form; more often, however, the first forking takes place comparatively early (fig. 6), and many adult prothalli were found in which one of these

branches had developed into the main prothallus-body, whilst the other had either broken away or persisted towards the base of the first in a state of arrested growth (figs. 4, 5, 6). The forking generally seems to result at first in two equal apices of growth (figs. 1, 2), and hence may be termed dichotomous, and, except in the case of the first branching as just described, which takes place when the prothallus is still comparatively small, the resultant branches become more or less equally developed (figs. 2 and 5). Hence in most adult prothalli found the original simple carrot-shape form had been lost, and the prothallus had become more irregular in appearance, such as is generally the case with epiphytic prothalli. Thus in this respect the prothalli of *Tmesipteris* can be compared with those of the epiphytic species of *Lycopodium* and *Ophioglossum*. In a few instances, moreover, such as those illustrated in figs. 6 and 66, a still greater irregularity of form had been brought about through the branching not taking place dichotomously. In the former of these two prothalli the forking seems to have been trichotomous. Still another irregularity in the form of adult prothalli is brought about by the equal development of both daughter branches at the first forking of the prothallus, not, as is usually the case, at an angle to one another, but in directions diametrically opposite (fig. 7). This is still more pronounced in the case of the large prothallus shown in fig. 8, in which one of the branches resulting from the first forking had forked again, the two branches of this second forking proceeding to develop in opposite directions to one another in the same straight line. Thus the branched form of the adult prothallus is attained normally by the dichotomous forking of the apex, but I observed also a few instances in which short undeveloped branches had arisen apparently laterally.

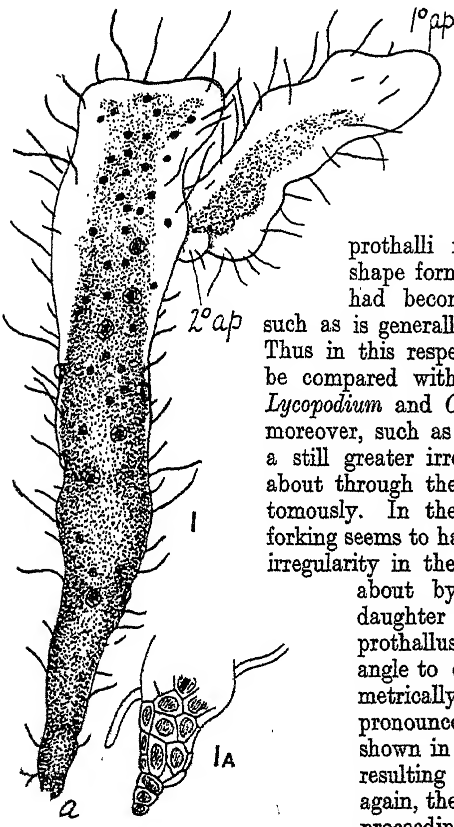


FIG. 1.—Complete prothallus, carrot form, bearing young plant, and showing original end intact. × 10.
FIG. 1A.—Original end of prothallus shown in fig. 1. × 24.

However, even in the most irregularly shaped adult individuals the manner of growth can always be easily traced, for even if the original long-drawn-out point be not preserved, yet the oldest region can always be distinguished from the rest of the prothallus by its darker brown or even almost black colour.

On some of the prothalli a large cup-shaped prominence with an obviously lacerated rim was to be seen (figs. 4 and 73). This is where a young plantlet had been broken away, the cup-shaped prominence having been formed by the localized outward growth of the prothallial tissues around the embryo and their final rupture by the developing plantlet. Such a point of attachment of the plant to its parent prothallus

may be seen sometimes in the lower regions of the latter (fig. 5), indicating that the growth of the prothallus is by no means arrested by the development on it of a plant, but may go on after the latter has attained a considerable size or has even become detached from the prothallus.

When first seen amongst the tangle of black aerial rootlets of the tree-fern stem the prothalli may easily be mistaken for broken portions of the rhizome of young plants or for very young complete isolated plantlets, and *vice versa*. Both the prothalli and the rhizomes are brown in colour, and both are covered fairly thickly with the long yellow-brown rhizoids

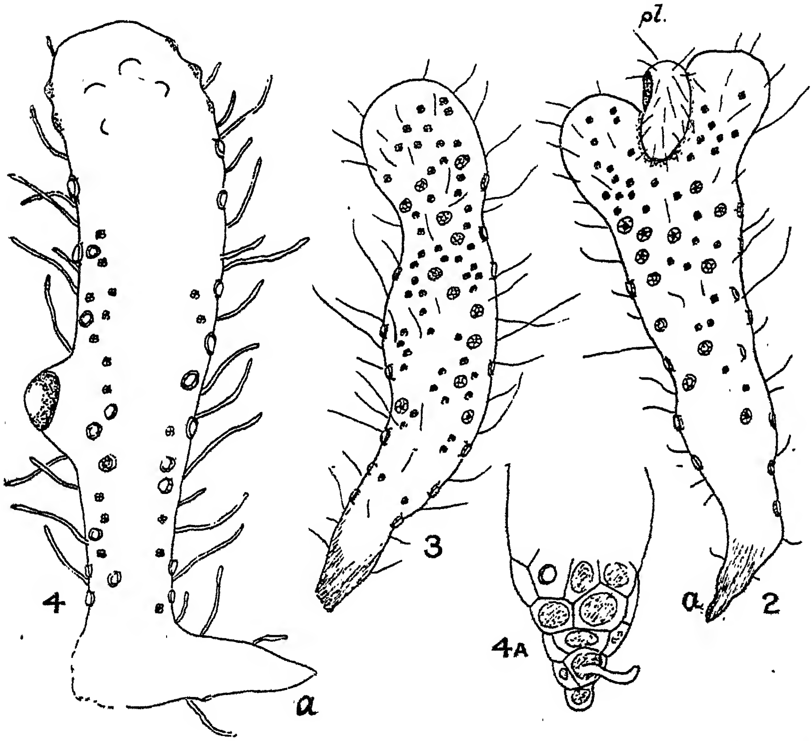


FIG. 2.—Complete prothallus, carrot form, commencing to fork, bearing young plant. × 9.
FIG. 3.—Prothallus, carrot form, original end broken off, showing swollen head. × 12.
FIG. 4.—Prothallus, branched, one branch broken off, shows original end intact, also point of attachment of young plant. × 12.
FIG. 4A.—Original end of prothallus shown in fig. 4. × 36.

or with the characteristic small brown circles formed by the persisting bases of broken-off rhizoids. The similarity holds also with regard to their growing apices, which are always somewhat swollen and are clear and whitish in appearance and show rhizoids only in their earlier stages of development. Each object dissected out has generally to be separately cleaned and examined under a low power of the microscope before its nature can be definitely determined. This is especially so in the case of the branched prothalli, whereas the carrot-shaped individuals are more easily recognized. However, generally speaking, the colour of the

prothallus is more opaquely brown than that of the rhizome, the latter appearing a clearer golden brown, with its surface cells outlined with great distinctness, this difference in appearance being due possibly to the denser fungal element in the interior tissues of the prothallus. The older basal regions of the prothalli are often darkly brown in

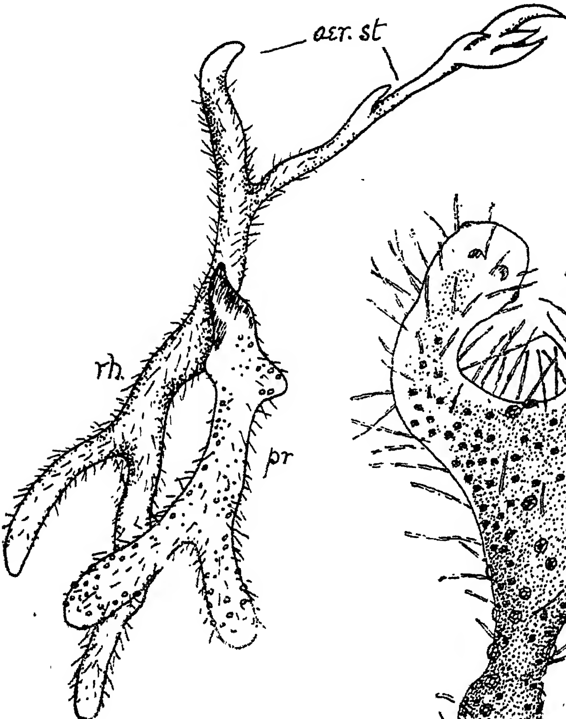


FIG. 5.—Complete branched prothallus of large size, bearing young plant which shows both rhizome and aerial stem. × 3.

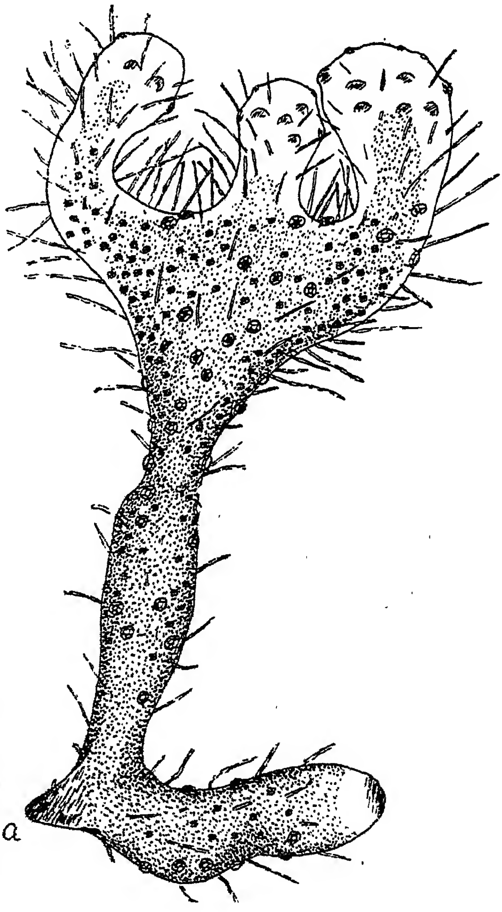
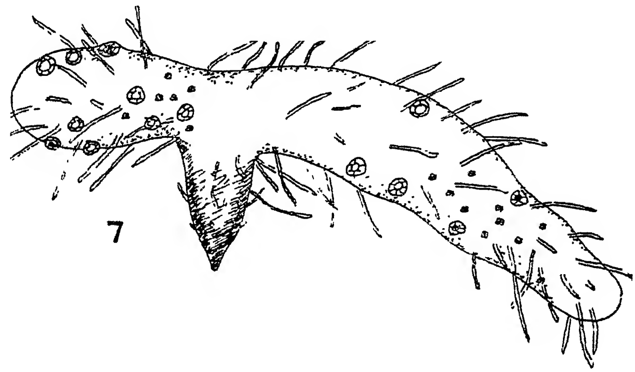


FIG. 6.—Complete branched prothallus of large size, one main branch showing further irregular branching. × 10.

colour or even blackish, owing not so much to any withering-away of the tissues as to the presence of the mycorhiza in this region in the cells immediately underlying the epidermis, and, in the oldest regions of all, in the epidermal cells also, as well as in those more centrally situated.

The prothallus in transverse section is round in outline (figs. 16 and 17), this being so throughout its length, so that its construction is consistently radial. Its growth in length is referable to the activity of a single cell (figs. 20 and 21), such as is the case also with the cylindrical prothalli of the Ophioglcssaceae. A transverse section through the main

body of the prothallus shows its tissues to be composed of cells of uniform size and shape, there being no differentiation of central long conducting cells or of fungal zones such as are so well known in most of the types of *Lycopodium* prothalli. The dense fungal coils occupy uniformly practically all the cells in the central region, the epidermis and a zone three or four cells in width immediately underlying it alone being free from these coils. In the limbs of the larger prothalli this subepidermal layer sometimes contains much starch. Moreover, meristematic activity sometimes shows itself in these cells (fig. 19), though whether in connection with the storage of starch or with the development of the sexual organs is not quite clear. The mycorhiza extends uniformly right up through the length of the prothallus to close behind the actual apex, keeping pace with the forward growth of the latter. A series of transverse sections behind a growing apex shows that at its uppermost limit the mycorhiza occupies only a narrow central



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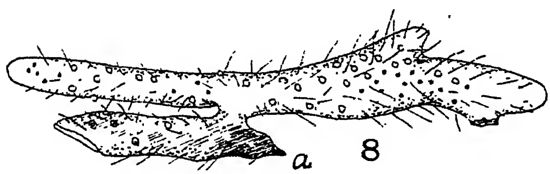

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FIG. 7.—Complete branched prothallus, in which the branches are not inclined to each other at angle but in opposite directions. × 10.
FIG. 8.—Branched prothallus, one branch broken; the other has branched again in the manner described for fig. 7. × 5.

core of cells, which gradually tapers off upwards, and that in these cells the hyphae are more scantily developed. The fungal hyphae in these growing regions of the prothallus are wholly absent from the cells which surround the central core, this fact showing that when once the mycorhiza has entered the prothallus in its earliest stages of development no further infection is needed, but that the fungus extends upwards in a uniform manner, keeping pace with the growth of the prothallus. The clear white colour of the actual apex is, of course, due to the absence of the fungus from its cells. In the older parts of the prothallus hyphae can often be distinguished penetrating through the length of rhizoids and across the outer layers of cortical cells, but it is probable (as is also considered to be the case in other pteridophytic prothalli which are infected with a mycorhiza) that this signifies no organic connection between the fungal

hyphae within the prothallus and those in the surrounding humus. A great outward growth of hyphae was noticed from the surface of teased-up portions of young rhizomes which had been kept for some days in water in a watch-glass, and many of the threads showed what seemed to be single round spores at regular distances along their length. At its uppermost limit the hyphae of the mycorhiza in the interior cells of the prothallus are scantily developed, but farther back the coils become more dense. Throughout the greater part of the prothallus the fungal contents of each cell show as a dense globular mass, in which the identity of the hyphal

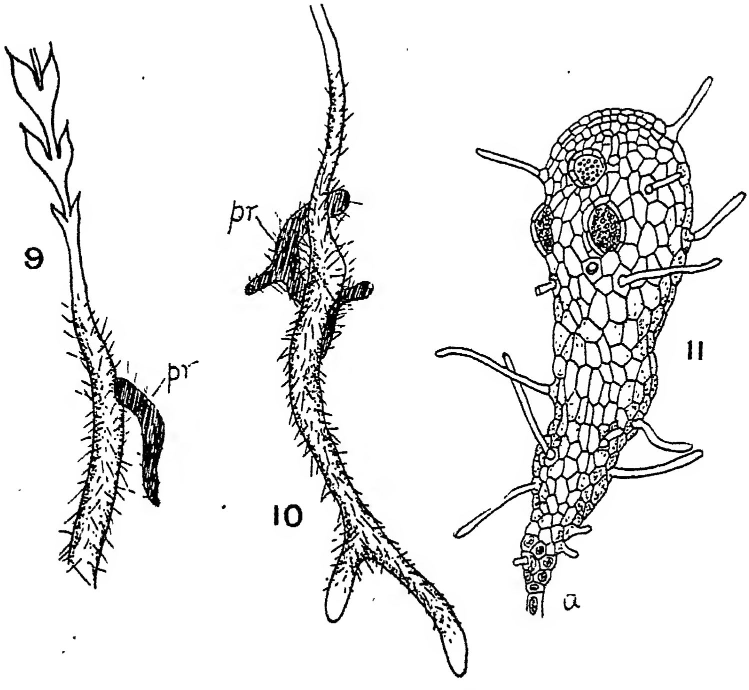


FIG. 9.—Old withered prothallus, carrot form, attached to plantlet which is broken above and below. × 3.
FIG. 10.—Old withered branched prothallus, attached to plantlet from which aerial stem is broken off. × 2.
FIG. 11.—Very young complete prothallus, showing original end intact and antheridia on its head. × 45.

threads can no longer be traced. These globular contents of the cells present a very characteristic feature both in the prothallus and young rhizome. (See Plate II.)

Not a few well-grown prothalli showed the original point of growth almost intact, and the remains of the first-formed filament, which arises, presumably, immediately from the spore, could be very clearly seen (figs. 1A, 4A, 11, 12, and 13). In two instances—namely, the very young prothallus shown in fig. 11 and the much older one in fig. 1A — there was present at the extremity of the basal end a short filament of cells, two or three in length, which in the former case was seen to be incomplete,

but in the latter was apparently quite complete. The prothallus shown in fig. 4A tapered off at the basal end to a single cell, which showed no sign of original farther extension such as would compare with the longer filament in figs. 1A and 11. But the single cell in which the basal point of most of the youngest prothalli found by me terminated did give evidence of having had a farther cellular extension broken away from it. In all these prothalli the terminal basal cells, whether single or in the form of a short linear filament, all contained the same dense masses of the fungal element which are present in the other parts of the prothallus. Thus it would seem that the fungus enters the prothallus immediately the spore begins to germinate, unless perhaps we take it that it spreads downwards into the filament subsequent to the infection of the prothallus through the first-formed rhizoids. Probably the delicate original basal filament owes its preservation to the fact of the presence in its cells of these fungal masses, the collapse of the cells being thus prevented. At any rate, the preservation of the actual original point of the prothallus of *Tmesipteris* in so many individuals, some of which were well grown, is rather remarkable. It would seem, then, though it must be stated that the remains of the originating spore itself have not been seen, that on germination the spore gives rise to a short linear filament of cells, and that this, after from one to three or more single cells have been cut off, proceeds to the formation of a cell-mass. This basal primary tubercle is well preserved in the prothalli shown in figs. 1, 2, 4, 11, 12, and 13, and it will be seen that in most cases it shows no great development. The further stages of growth of the prothallus can be clearly seen from a comparison of the young and the older individuals shown in these figures. The prothallus grows in a succession of gentle swellings, each a little bigger than the last, the increased cell-multiplication which these swellings indicate being due probably to the accumulation of food material at the apex, consequent on the activity of the mycorhiza. In fig. 14 is shown one of the limbs of the large prothallus illustrated in fig. 6; serial sections through this limb showed that the cells of the apical region were packed with starch. Thus, as the prothallus grows, its apex becomes more and more bulky, so that the whole prothallus-body acquires the carrot form, until at length, owing probably to the stimulation set up by the presence of abundant

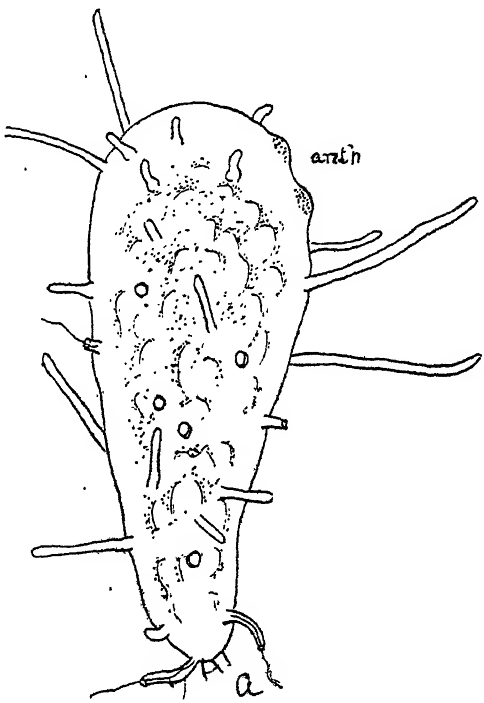


FIG. 12.—Very young complete prothallus, showing papillose-like outgrowth of epidermal cells. Antheridia on head. × 45.

food contents in its cells, the head of the prothallus forks and the carrot form gives place to the branched form characteristic of the full-grown individuals.

The Distribution of the Sexual Organs.

There is no differentiation of the prothallus into vegetative and reproductive regions, such as is usual, for example, in the terrestrial forms of *Lycopodium* prothalli. The sexual organs are distributed over the surface of the whole prothallus-body in large numbers, and often in groups. A transverse section of the limb of a prothallus will often show either antheridia or archegonia distributed more or less all around the surface (figs. 16 and 17). The sexual organs are for the most part more intermingled than is the case in the branched prothalli of the epiphytic lycopodiums, and correspond in this particular rather to the prothallus of *Ophioglossum* (Campbell, 1911, p. 10).

The young developing sexual organs are to be found immediately behind the growing apex of the prothallus, but also, as is known to be the case in *Ophioglossum* (*ibid.*, p. 29), they frequently arise much farther back from it amongst old organs. As a rule, however, both the antheridia and the archegonia arise immediately behind the growing apices in acropetal succession. In nearly every prothallus I noticed developing antheridia on the growing branches, in some cases the youngest being fairly close behind the actual apex, whilst in others (where possibly the growth in length of the branch was taking place more rapidly) at a greater distance back from it. In only a very few out of the large number of prothalli found by me were groups of young archegonia to be seen close behind the apex. This fact, however, is probably due to chance only, for archegonia always occur in large numbers on the main prothallus-body, though the tendency to grouping is more to be remarked in the distribution of the archegonia than of the antheridia. It may possibly be that the archegonia arise in an irregular manner on older parts of the prothallus more frequently than do the antheridia. In several instances of adult prothalli (figs. 1, 2, and 3) where growth had slackened, old archegonia were present in fairly large numbers close behind the apex.

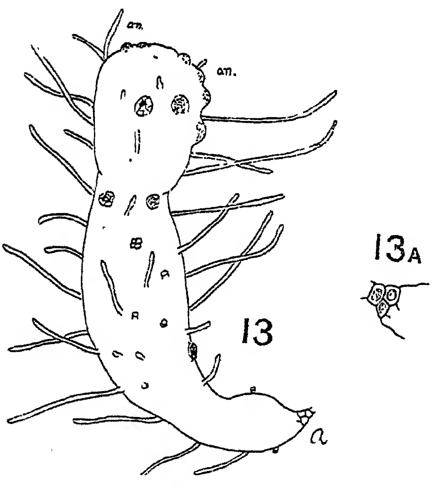
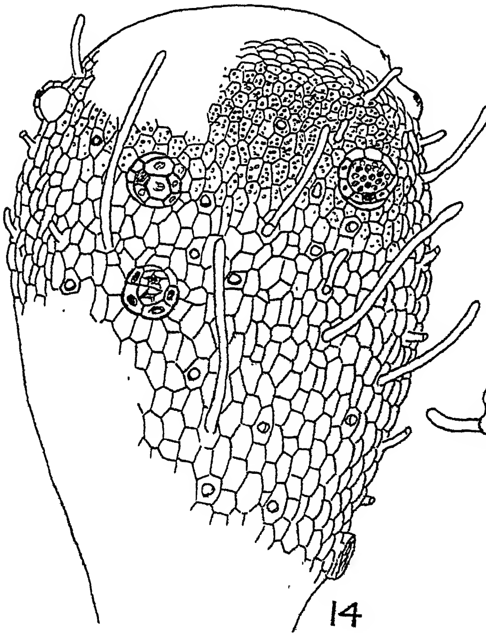


Fig. 13.—Young complete prothallus, showing swollen head, sexual organs, and original end. × 16.
Fig. 13A.—Original end of prothallus shown in fig. 13. × 30.

In the very young prothalli shown in figs. 11 and 12 it will be seen that the sexual organs begin to develop comparatively early, and that it is the antheridia that are first formed. The basal regions of older prothalli also generally show the presence of old antheridia. In surface appearance the young developing antheridia are seen as colourless hemispherical proturberances (figs. 6, 12, 13, &c.). This is generally one of the most

marked features of the growing head of the prothallus. Developing antheridia in surface view are shown in fig. 14. There is a single opercular cell at the apex of the protuberance, whose walls early become brown in colour, thus defining the cell very clearly. This browning soon extends to the walls and contents of all the outer cells on the free portion of the antheridium. In the ripe antheridium the interior mass of spermatocytes can clearly be seen in surface view. The antheridium is emptied through the breaking-down of the opercular cell, the aperture thus formed becoming enlarged in still older individuals by the breaking-away also of those cells which adjoin the opercular cell. Thus the characteristic appearance of old antheridia all over the main prothallus-body is that of brown cup-shaped structures projecting from the prothallus-surface (fig. 14, &c.).



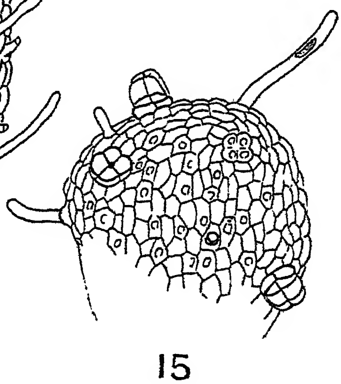


FIG. 14.—One of the large heads of prothallus shown in fig. 6, with antheridia in various views. × 52.

FIG. 15.—Small head of a prothallus, showing archegonia in various stages of development. × 66.

The young archegonium is first visible in surface view from the division into four of its outer cell and their arrangement quadrantwise. At first, near the apex of the prothallus, this group of four cells is colourless, but in older organs the cell-walls and the aperture of the neck-canal between them becomes brown in colour, and the archegonia are thus clearly defined in surface view (fig. 15). The neck of the archegonium early projects from the surrounding epidermal cells, and is straight rather than curved. Generally speaking, in older parts of the prothallus the neck has broken short off, so that the characteristic appearance of the group of four cells which surround the aperture of the archegonium

in these cases is that of the lowest tier of neck-cells. In fig. 15 is shown the head of a small limb of a prothallus with archegonia in different stages of development, in surface view.

There are not lacking signs of dorsiventrality in the distribution of the sexual organs, but these are probably unimportant. For example, the old antheridia are sometimes much more numerous along the edges of the prothallus (in the plane in which it naturally lies), and also at the growing apices the young antheridia sometimes occur more numerously towards the edges. This tendency to dorsiventrality is more apparent still in the fact that in some of the younger prothalli one surface was

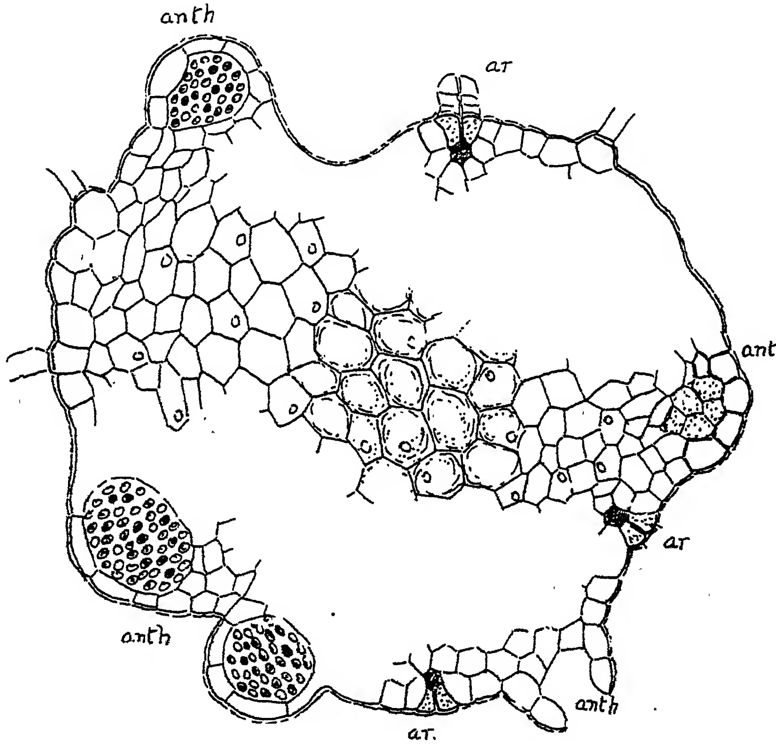


FIG. 16.—Transverse section of limb of prothallus behind growing apex, showing antheridia and archegonia. × 100.

noticed to be almost if not entirely free from rhizoids and sexual organs, whilst the opposite surface bore them both. In the young prothallus shown in fig. 12 one surface was quite naked and smooth, but on the other there were a fair number of rhizoids, and the surface was noticeably rough on account of the protruding of the epidermal cells in a papillose manner, and also at the edges were both rhizoids and antheridia to be seen. These indications of dorsiventrality in the distribution of the sexual organs are not, however, always to be observed, and, on the whole, both antheridia and archegonia may be said to be distributed more or less evenly around the surface.

DEVELOPMENT OF THE SEXUAL ORGANS.

As has been stated in the preceding section, developing antheridia were commonly seen at the growing apices of the prothalli, but only in a very few prothalli did I find groups of young archegonia. In the older regions of the prothallus, where both antheridia and archegonia not infrequently arise singly amongst old organs, I did not find any in the earliest stages of development, though many of both kinds in later stages were to be seen. The fact that the apex of the prothallus is generally very broad militated somewhat against the study of the young developing organs, for transverse sections in this curving region of the prothallus-head cut

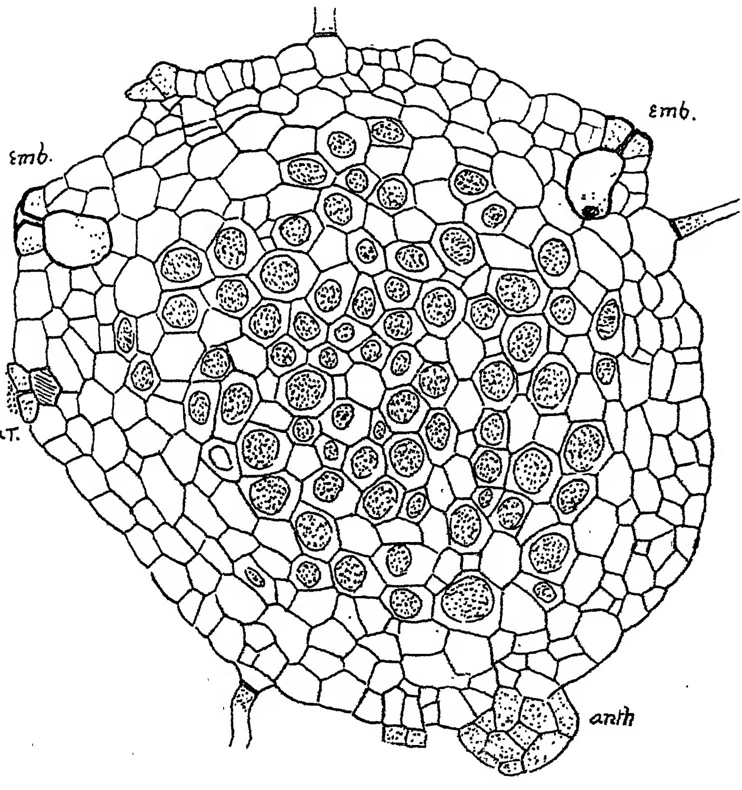


FIG. 17.—Transverse section of main limb of prothallus in older region, showing portions of old sexual organs, also two fertilized archegonia. × 100.

them often obliquely. However, I was able to obtain a fairly good series of both, although certain points must be left for a more complete study.

Perhaps it would not be out of place for me to describe at this juncture the methods adopted for the preparation of my material for microscopic investigation. After the preliminary study and drawing of each prothallus as it was dissected out of the tree-fern humus, it was killed and fixed by immersing for twenty-four hours in a solution of chromo-acetic acid, the formula for which is that given by Chamberlain on p. 21 of his *Methods in Plant Histology* (3rd ed., 1915). This was found to answer quite satisfactorily so far as the more obvious histology of the prothalli and sexual

organs was concerned. Some of the material was sectioned by the microtome, but I found that it showed a tendency in the older regions to resist infiltration by the paraffin. I was inclined to ascribe this to the very dense nature of the fungal element. The prothalli of *Tmesipteris* are so firm and large that I decided to hand-cut a number of prepared specimens (having no lack of material) in order to supplement my serial sections with others to as great an extent as possible. I found that, on the whole, the hand-cut sections gave good results, being free from the shrinkage so often associated with the microtome sections. Moreover, they took the stain better. The obvious disadvantage of the hand-cut sections is that they are not kept in

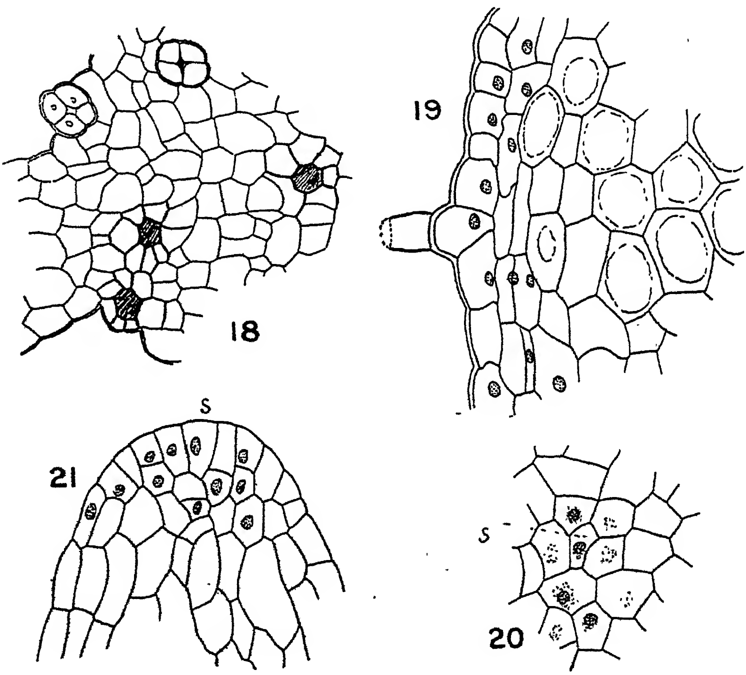
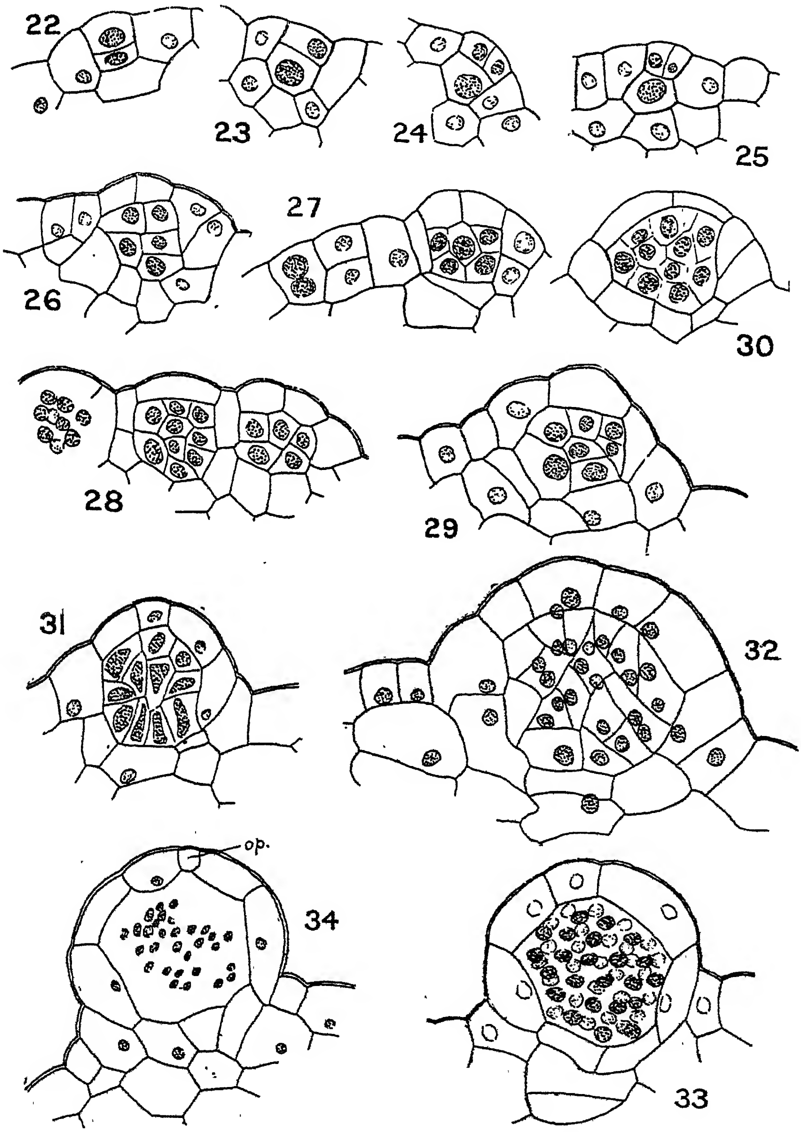


FIG. 18.—Portion of main limb of prothallus in tangential longitudinal section, showing archegonia. × 70.
FIG. 19.—Portion of main limb of prothallus in transverse section, showing meristematic activity underneath the epidermis. × 137.
FIG. 20.—Transverse section of apex of prothallus, showing single apical cell. × 137.
FIG. 21.—Longitudinal section of apex of slender limb of prothallus, showing single apical cell. × 137.

proper sequence. I used throughout Delafield's haematoxylin as a stain, combining it with safranin for the vascular tissues. This haematoxylin was very satisfactory, especially for differentiating the young embryos. However, this method of staining failed to show anything of the process of spermatogenesis. Campbell (1911, p. 28) recommends using the combination stain safranin and gentian violet for this purpose, as, indeed, generally for prothallial work.

In detecting the youngest stages in the development of the sexual organs one is guided by the fact that they occur in close association with others and also with slightly older organs, and also by the greater size of their

nuclei and the deeper staining both of these and of their other cell-contents than is the case in the ordinary vegetative cells. They do not arise so near the actual apex of the prothallus as is the case in the Ophioglossaceae or as I have found in the epiphytic prothalli of *Lycopodium Billardieri*.

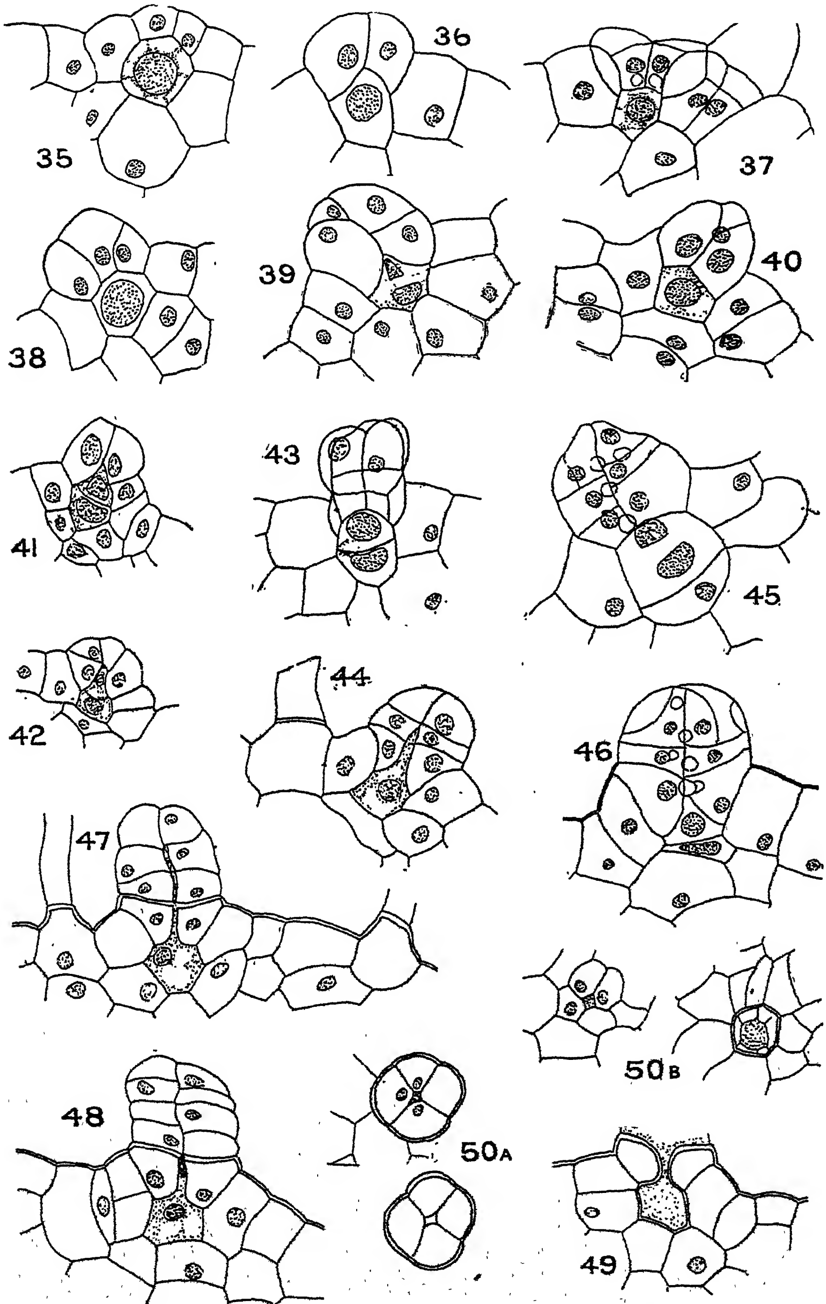


FIGS. 22–33.—Series showing the development of the antheridium. × 150.
FIG. 34.—Mature antheridium, showing opercular cell. × 137.

In the development of an antheridium from an epidermal cell the first division wall to be formed is a periclinal one cutting off an outer from an inner cell (figs. 22 to 25). Sometimes the inner of these, and at

others the outer, is the larger. The mother cell does not at first project beyond the surface of the prothallus, but by the time the first division in it has taken place it has enlarged considerably and has begun to project noticeably. The next division takes place in the outer cell by an anticlinal wall (figs 24, 25). I have no direct information as to the exact sequence of divisions which takes place in the cover-cell, but it is clear that it gives rise to the whole of the outer free wall of the antheridium, whilst from the inner cell is formed the mass of spermatocytes. From figs. 26 and 28 it would seem that a good deal of segmentation takes place in the inner part of the developing antheridium before the outer wall begins to project at all strongly. I did not observe in my preparations any instances of an antheridium in this stage in transverse section, but it will probably be the case that quadrant and octant divisions are formed in the inner cell, as is known in other Pteridophytes. The free wall of the antheridium is never more than one cell in thickness. The mature antheridium projects very strongly beyond the surface of the prothallus as a hemispherical globular body, the number of cells in the free wall being large. From mature antheridia seen in surface view (fig. 14), it is evident that the division walls in the cover of the antheridium intersect one another more or less at right angles, so that the opercular cell is four-sided. This cell is situated at the apex of the antheridium, and is first to be distinguished in surface view by its walls becoming brown in colour (fig. 14). This browning later extends to the adjacent cell-walls, and, before the antheridium has discharged, both walls and contents of most of the cover-cells in the exposed portion of the antheridium have assumed the same coloration. The interior cells of the antheridium rapidly subdivide (figs. 29 to 33), so that a large number of spermatocytes is formed, although the number is not so great as in certain of the Ophioglossaceae and in the subterranean types of *Lycopodium* prothalli. From the adjacent prothallial cells a wall of more or less flat cells is cut off surrounding the lower portion of the antheridium. The opercular cell seems to vary in size for different antheridia. Rupture of the antheridium is initiated by the disorganization of this cell, while in still older antheridia it is generally to be observed that the cells of the outer wall which adjoin this aperture have also broken down, so that the characteristic appearance of the numerous old discharged antheridia on the main prothallus body is that of small brown saucer-like structures projecting from the surface. The details in the formation of the sperms were not followed. I was unsuccessful in my endeavour to make the sperms swarm in fresh prothallial sections, and the method of staining was not suitable for showing the details of spermatogenesis. Possibly, also, a better killing and fixing solution would have to be sought for this purpose.

The earliest stages in the development of the archegonium are to be distinguished by the very large size of the nucleus in the inner cell. As in the young antheridium, the first wall to be formed is a periclinal by which an outer is cut off from an inner cell. The outer or neck cell divides next by an anticlinal wall (figs. 35, 36), a surface view showing that two such walls are quickly formed intersecting at right angles, so that the archegonium neck-cells have the usual quadrant form (fig. 15). These four cells give rise to the neck of the archegonium, and soon project sharply beyond the surrounding epidermal cells (figs. 36 to 38, and 40). My preparations show that up to this point the inner cell has not divided, but has merely pushed up slightly between the neck-cells along with the



FIGS. 35–49.—Series showing development of the archegonia. Figs. 35–41 × 150; fig. 42 × 137; figs. 43–49 × 150.
FIGS. 50A, 50B.—Series of transverse sections through mature archegonium from above downwards. × 137.

outward growth of the latter. Thus a basal cell to the archegonium is not formed. In figs. 39, 41, and 42 it will be seen that the large nucleus of the inner cell next divides, and a horizontal wall is formed, this (according to my interpretation) cutting off a neck-canal cell from a central cell. This neck-canal cell seems to be evident in the slightly older archegonia shown in figs. 43 and 46. The neck-cells lengthen considerably, and divide by horizontal walls generally two or three times, so that a straight neck is formed (figs. 15, 45, 46) of three or four tiers of cells. The neck-canal cell pushes up between the neck-cells, and probably divides once or twice in the usual way, although I could not demonstrate this, except perhaps in the instance shown in fig. 45—much less was a ventral-canal cell to be traced. In fig. 15 is shown the rounded apical head of a small prothallus branch on which two archegonia will be seen with protruding necks. In these cases the neck consists of the lowest tier of cells, which have already taken on the characteristic brown coloration, and an upper tier of elongated cells which will divide again by two or three horizontal walls. As soon as the outermost tier separate the neck-canal becomes conspicuously brown. Sooner or later, after the archegonium has matured, the outer three or four tiers of neck-cells fall off, leaving only the lowest tier, whose walls become strongly cutinized. These cells have already assumed the brown colour in their walls, and their nuclei and contents soon do the same. The exposed horizontal walls of this tier of four cells slope inwards towards the canal in a saucer-like form (fig. 15). Although an occasional old archegonium may be seen on the older parts of the prothallus still showing the full length of neck, yet the characteristic appearance of old archegonia is that just described, the four brown rather peculiarly projecting neck-cells, which originally constituted the lowest tier in the neck, surmounting the brown egg-cell (figs. 47 to 49). A close inspection not infrequently shows the remains of the broken-off cell-walls still attached to the outer surface of these persisting neck-cells.

The Development of the Embryo.

Unfertilized old archegonia are abundant on most parts of the main prothallus-body, and are very evident on account of the brown colour of the egg-cell and of the persisting lowest tier of neck-cells. I sectioned a good number of large prothalli on which I found no fertilized archegonia at all, but there were several prothalli on which I found both fertilized archegonia in which the egg-cell had not as yet shown any cell-division, and also several young developing embryos. Also I obtained a number of prothalli which bore single young plantlets in various stages of development, while most of the largest prothalli showed the presence of the ruptured cup-like eminence from which a young plant had become detached. Thus although developing embryos do not occur on the prothalli of *Tmesipteris* as numerously as in certain of the large terrestrial species of *Lycopodium* prothallus (*vide*, *e.g.*, Bruchmann, 1898, p. 37), yet it ought to be possible to obtain a complete series. It was to be noticed that in several instances both the fertilized archegonia and also the developing embryos were grouped, whilst one embryo was found close alongside the point of attachment of a young plantlet. Fig. 17 shows a transverse section of a prothallus in which two fertilized egg-cells are to be seen. It may be noted here that I found Delafield's haematoxylin a satisfactory stain for differentiating clearly the young embryos from the surrounding tissue. After fertilization the egg-cell grows considerably in size (figs. 17, 51, 52)

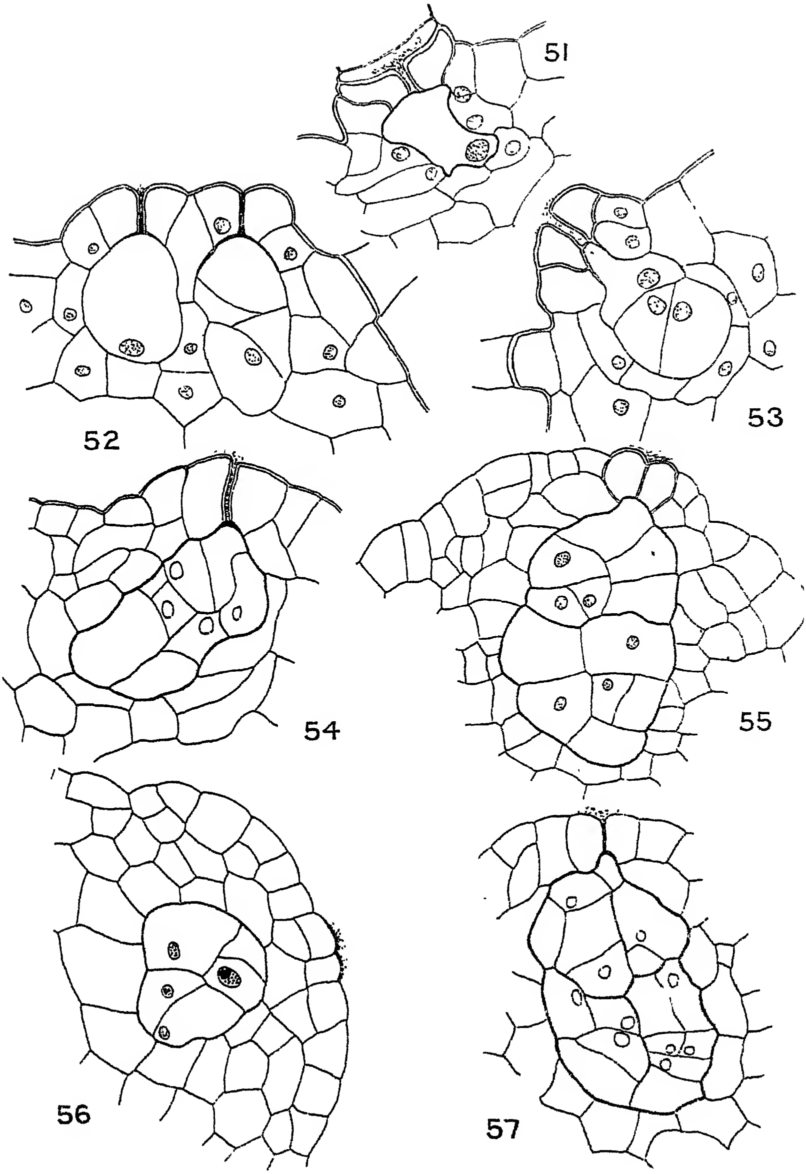


FIG. 51.—Longitudinal section of fertilized archegonium. × 175.

FIG. 52.—Longitudinal section of two fertilized archegonia, in one of which segmentation has begun. × 175.

FIG. 53.—Longitudinal section of very young embryo, showing earliest segmentation. × 175.

FIG. 54.—Median longitudinal section of young embryo. × 137.

FIG. 55.—Median longitudinal section of young embryo. × 137.

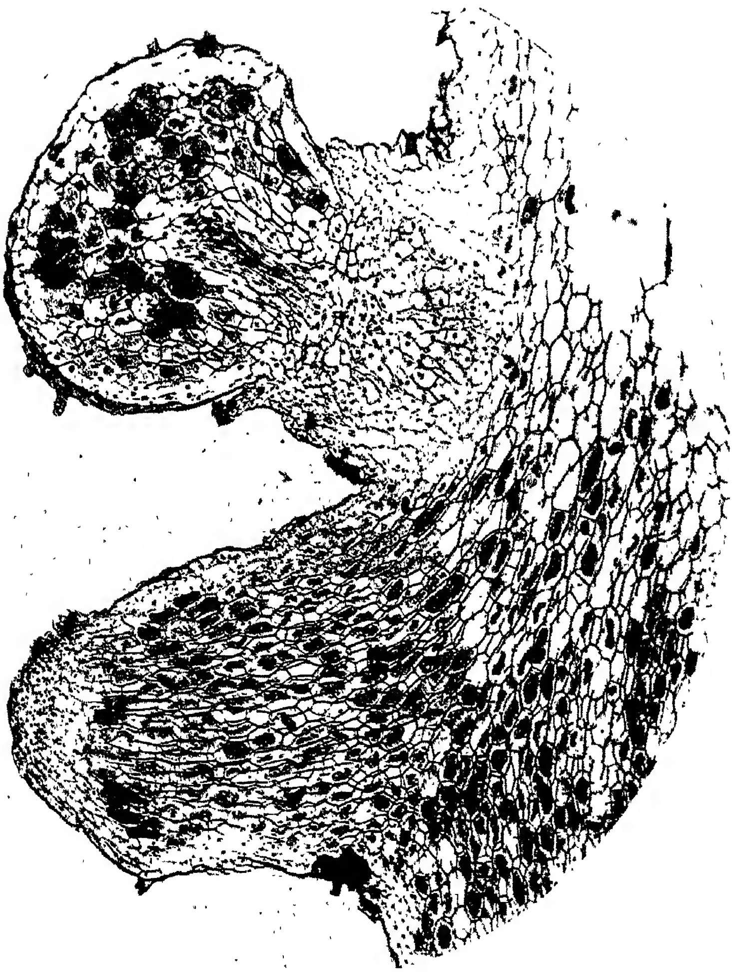
FIG. 56.—Tangential longitudinal section through upper portion of same embryo as shown in fig. 55. × 137.

FIG. 57.—Median longitudinal section of young embryo. × 137.

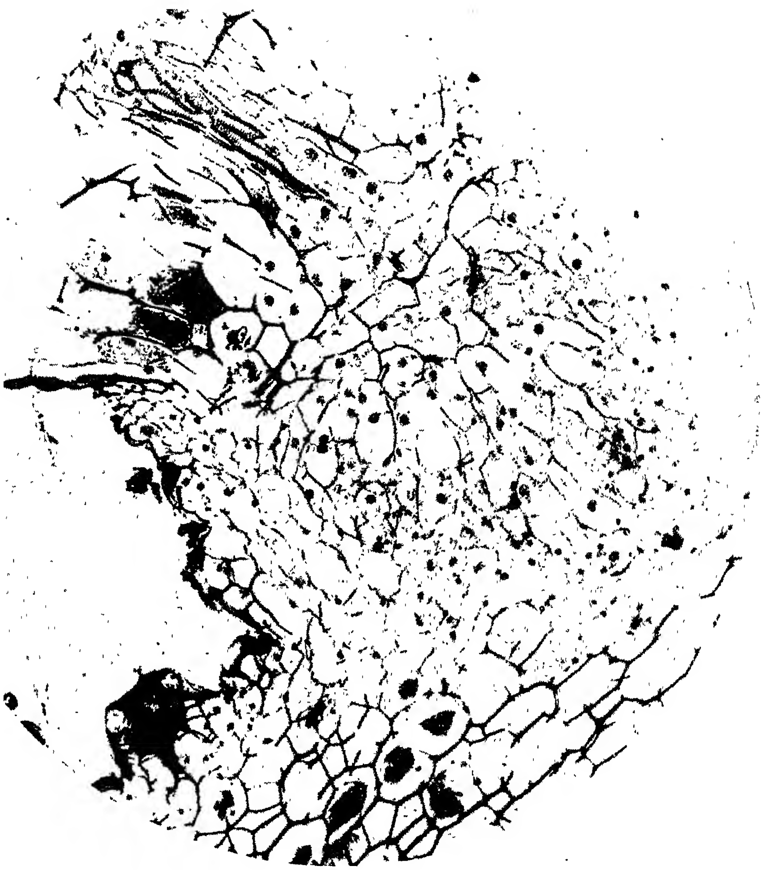
and the nucleus retreats (at first, at any rate) to the inner end of the cell. The ovum surrounds itself with a delicate membrane, which arches up somewhat into the base of the neck-canal of the archegonium and at that point thickens. It grows to a fairly large size before it segments, somewhat, though not to the same extent, as Bruchmann has described in the case of *Lycopodium clavatum* and *L. annotinum* (Bruchmann, 1898). The first division wall to be formed is more or less transverse to the axis of the archegonium, and seems to be approximately in the middle of the cell (figs. 52, 53). This wall thus divides the embryo into what we may speak of as the lower and upper regions. This first division may be clearly traced afterwards in older embryos. The next division wall to appear is in the lower half, and extends at an angle from the first wall to the lower end of the embryo (figs. 52, 53). It also may be clearly seen in older embryos. No embryos were found in transverse section, so that this description of the earliest stages in segmentation can only refer to the appearance of the embryo in longitudinal section. Still older embryos are shown in figs. 54, 55, and 57. I find it difficult to describe with any degree of certainty the sequence of segmentation which has taken place either in the lower or in the upper parts of these embryos.

In addition to the section of the embryo shown in fig. 55, already referred to, a second section (fig. 56), obviously not so nearly median, shows a part of the same embryo which I am inclined to think is the stem-rudiment. In it there are two main walls intersecting at right angles, and in one of the cells so formed another wall has appeared cutting out what might well be an apical cell. This part of the embryo took the haematoxylin stain rather more darkly than did the rest, and the nucleus of the "apical" cell was conspicuously large, the suggestion being that this part was forming rapidly. It will be evident from a comparison of the two sections of this embryo that this portion which we are now considering belongs to the upper region and has arisen laterally from it. If it proves to be correct that the shoot originates from the upper half, this fact would distinguish the embryo of *Tmesipteris* from that of the Lycopodinae, where the upper primary segment constitutes a suspensor, but would, on the other hand, suggest the embryo of *Equisetum* and the Ophioglossaceae. Of course, one main reason why the embryo of *Tmesipteris* is likely to prove of special interest is the fact that the adult plant has no root, consisting only of an underground branched rhizoid-bearing rhizome and an aerial branched leaf-bearing portion. Anticipating here what I shall be bringing forward in connection with the developing plantlet, we may say that the young plant of *Tmesipteris* is "all shoot," just as the embryo of certain members of the Ophioglossaceae has been described as "all root." The question naturally arises whether there is in the embryo of *Tmesipteris* anything which may be interpreted as the undeveloped rudiment of a root. Only a much fuller study of the development of the embryo than that given above can satisfactorily decide this point. I hope to be able to gather more material for such a study. The stages described above stop short at a most interesting point, and I have found it difficult to interpret some of them. Keeping pace with the growth of the embryo, the surrounding prothallial cells rapidly subdivide, so that the embryo is enwrapped by a small-celled tissue which soon begins to project as an eminence from the side of the prothallus (figs. 55, &c.).

Before passing on to the section of this paper which deals with the developing plantlet there is still an important and interesting point to be brought forward which concerns the question of the "foot" of the



Longitudinal section, prothallus of *Tmesipteris*, showing young plant attached. (Photomicrograph.)



Longitudinal section, point of attachment of young plant of *Tmesipteris* to the prothallus. (Photomicrograph.)

embryo. Longitudinal sections through the point of attachment of a young plantlet to its parent prothallus, such as that shown in figs. 58 and 59, and in Plates II and III, in all of which the plant-axis is in transverse section, but the foot in longitudinal section, reveal the fact that the region of the plantlet which is in immediate contact with the prothallial tissues—*i.e.*, the "foot" or absorbing region—is prolonged into a large number of long haustoria-like processes, which penetrate the tissues of the prothallus and evidently function as absorbing organs. These processes are generally two cells wide at their base, whilst the forward end of each is prolonged into a row of single cells, the terminal cell of the row being more or less elongated

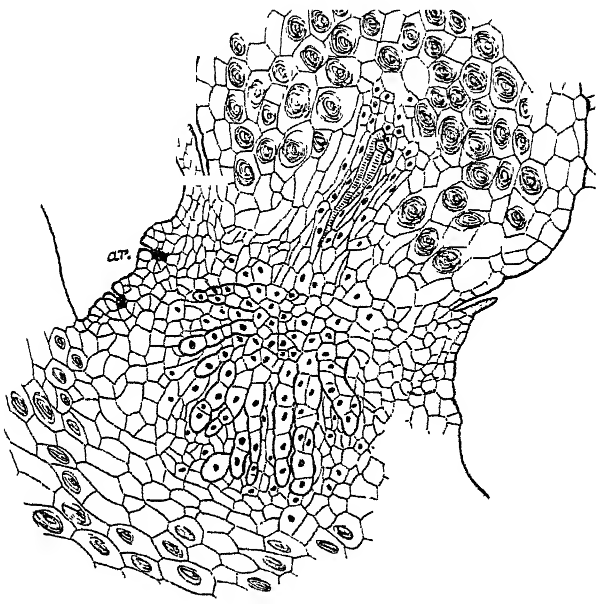


FIG. 58.—Transverse section of young plantlet through point of attachment to prothallus, showing foot and haustorial outgrowths. × 42.

and rounded. They emanate, appearing in section like the fingers of a hand, from a region which consists largely of cells which are dividing. The cells both of the processes and of the region from which they arise stain very conspicuously with haematoxylin both in their walls and nuclei. In transverse section the processes are circular in outline. This will be seen in fig. 60, which also shows the nature of the surrounding prothallial cells. On the side towards the plant-axis the cells gradually increase in size, and median sections through the whole plant-foot reveal the fact that vascular tissue, both xylem and phloem, extends from the plant-axis into the foot. In fact, longitudinal sections of detached plantlets of similar age such as that shown in fig. 68 indicate that the entire vascular bundle of the young plant inclines at an angle into the foot. The obvious explanation would be that at an early stage in the development of the young plant

an apical meristem is set apart from which a plerome strand arises, and that this strand of tissue functions solely in the transportation of food from the parent prothallus up to the growing apex of the shoot. There is nothing to indicate a possible root-rudiment. The haustorial processes are many in number, and no one of them more than any other could be suspected of being such a degenerate or arrested root organ. There is also the broad zone of meristematic cells lying between these processes and the axis of the plant. Of what nature is this? Only a series of embryos more complete than that described in this paper can indicate at all satisfactorily the first differentiation of the embryo into shoot and foot, and whether or not a root-rudiment is present. If the shoot develops from the lower half of the embryo, then there would necessarily have to be a curvature in the forward growth of that region (as in the *Lycopodium* embryo) so as to allow the shoot to emerge, as it certainly does, at the apex of the prothallial eminence on which the embryo has been developing. The segmentation in the upper primary half of my embryos is certainly not as clear and regular as it is in the epibasal region of the *Equisetum* embryo, which there gives rise to the shoot-axis; but, on the other hand, it does not suggest the Lycopod suspensor. My own opinion, based upon the study of the embryos described in this paper and of the young plantlets, is that the shoot arises from the upper region (*i.e.*, nearest the archegonial neck), and that the lower half gives rise only to the foot, the surface cells of the latter growing out into the peculiar haustorial processes. I see nothing to indicate a root. There is no cotyledon, the first leaves being formed at a very late stage as mere scales from the apical cell of the shoot after the latter has emerged from the surface of the humus and has changed its character from a rhizome to a green aerial stem.

A still younger plantlet than that just described is shown in median longitudinal section in figs. 61 and 62. The shoot took the form of a globular protuberance from the surface of the prothallus. Sections through the foot showed that the characteristic haustorial outgrowths were only in the first stages of formation. The spherical shoot showed at one point a slightly conical projection, which in section was seen to be composed of meristematic tissue. This was obviously the actual apex of the shoot, but no vascular strand had as yet arisen from it. The main portion of the shoot consisted of large uniform cells in which the coils of the mycorhiza were already established. The apical region consisted of smaller regularly arranged cells, free from fungus, and showing conspicuous nuclei. I was not able to distinguish whether or not there was a single apical cell present. Fig. 61 shows the plant as a whole in median longitudinal section, but the shoot-apex is cut somewhat obliquely, as its direction of growth did not coincide with the plane of the section. From a study of this particular plantlet I am still more of the opinion that the embryo gives rise to two main organs only—viz., the foot and the shoot—the former arising from the lower half and the latter from the upper. Whether or not a definite stem-apex is differentiated early in the embryo my material does not show, although the embryo shown in fig. 56 would seem to indicate this.

Development of the Young Plant.

A good number of prothalli were found on which single young plants in various stages of development were borne. Also, I dissected out of the tree-fern humus a large number of complete plantlets which had become

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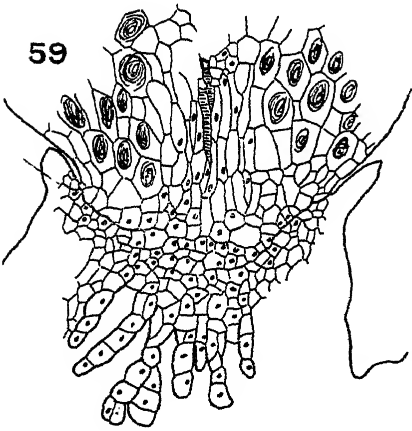

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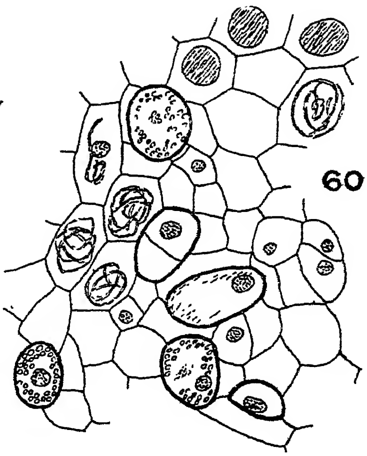

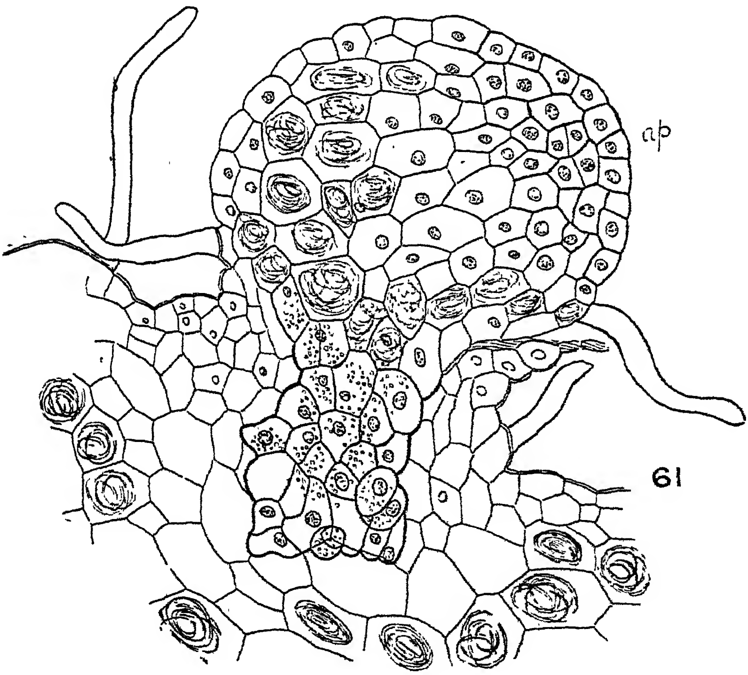

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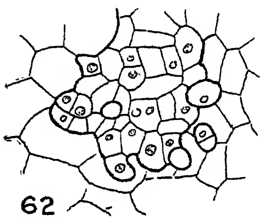
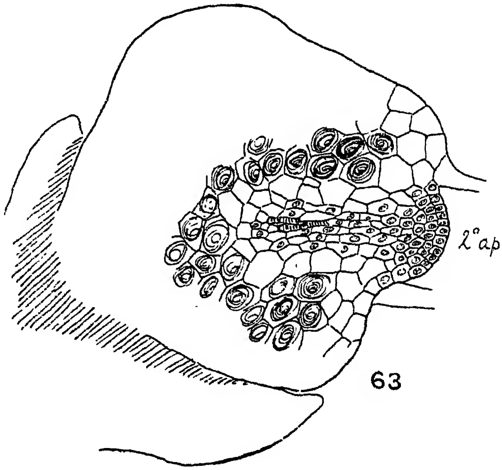
FIG. 59.—Section through point of attachment to prothallus of same young plantlet as shown in fig. 58, to show manner of detachment of plant from prothallus. × 42.

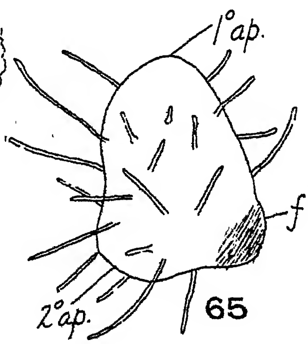
FIG. 60.—Tangential section through foot of young plantlet shown in fig. 58, showing haustorial outgrowths in transverse section. × 125.

FIG. 61.—Median section through very young developing plantlet, showing foot and apical region. × 84.

detached from their parent prothalli. I am thus able to give a connected account of the development of the young plant. The earliest stages, in which the young shoot has just broken through the surface of the prothallus, and before a vascular strand has made its appearance (see fig. 61), has







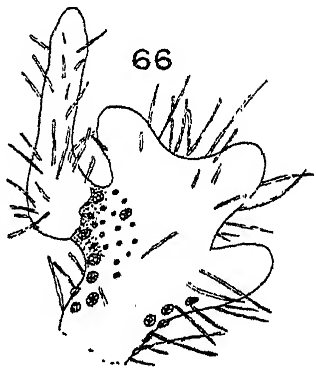


Fig. 62.—Section through foot of same young plantlet as shown in fig. 61, showing outgrowth of epidermal cells of foot. × 74.

Fig. 63.—Transverse section of young plantlet similar to that shown in fig. 68, showing initiation of secondary apex of growth. × 64.

Fig. 64.—Very young detached plantlet, showing apex of growth, and fragment of prothallial tissue attached to foot. × 18.

Fig. 65.—Very young detached plantlet, showing foot and both primary and secondary apices of growth. × 16.

Fig. 66.—Young developing plantlet attached to prothallus; secondary apex of growth not yet developed. × 8.

been described at the end of the last section. The shoot-apex in this particular plantlet had already been differentiated, though precisely at what stage in the development of the embryo I cannot say for certain. The subsequent elongation o: the originally spherical shoot takes place at this apex. In figs. 64 and 65 are shown two early stages in the develop-

ment of the young plant, in these cases the plantlets having become detached from their parent prothalli during the process of dissection. I have no plantlets of this age in section, but judging from its conical and somewhat pointed shape I would say that the actual apex is occupied by a single apical cell. That end of the young plant which is opposite to the growing apex is obviously the "foot" or absorbing region, where the plant was in connection with the prothallus. In the detached plantlets shown in figs. 64 and 65 this end is roundish in outline, it being evident that the haustoria-like processes of the foot had been left embedded in the tissues of the prothallus. Still older plantlets consist of a lengthening undifferentiated rhizome, golden-brown in colour, thickly clothed with long straight golden-brown rhizoids. Where the rhizoids are broken off, characteristic ring-like outgrowths are left projecting slightly from the epidermal cells. The latter are brown in colour, and, owing to the clear colour of the rhizome generally, stand out very distinctly in outline. The original point of attachment of a detached plantlet of this age to its parent prothallus can always be readily distinguished as a dark circular patch situated on a slight but distinct conical prominence at the basal end of the rhizome. Sometimes there is a brown fragment of prothallial tissue which may show old sexual organs still attached to this foot-prominence.

The manner of detachment of the plant from its prothallus may best here be described. It was found during the process of dissecting that the plantlets very easily become detached from their parent prothalli. Reference to the longitudinal section of the plantlet and prothallus given in fig. 59 will show that a saucer or cup-shaped line of dehiscence extends from the edge, where the developing plant has ruptured the tissues of the prothallus, down into the central regions of the foot. This line of dehiscence is clearly marked out by the browning of the cell-walls along the line. Figs. 58 and 59 show clearly both how readily the plant can become detached from the prothallus, leaving behind in the tissues of the latter the haustoria-like processes, and also how the large cup-like point of attachment, which so often is a characteristic feature on full-grown prothalli, comes to be formed.

All the youngest plantlets found, whether detached or still in connection with the prothallus, showed only one apex of growth, the other end of the plantlet being bluntly rounded and in no way differing in external appearance from the rest of the rhizome surface (figs. 66 and 67). The point of attachment to the prothallus was at this undifferentiated end of the plant. Longitudinal sections of the prothallus and plant shown in fig. 66 revealed that there was nothing at this end of the plant to indicate an apex of growth. Sooner or later, however, a new apex of growth is differentiated at this point (figs. 1, 68, 69), and the young rhizome then proceeds to grow in length in a direction more or less exactly opposite to the primary direction of growth. This new portion of the plant-rhizome is sometimes in a straight line with the first-formed shoot axis (fig. 70), but more often is inclined to it at an angle, the brown point of attachment in the latter case being then to be seen on the angle (figs. 65, 69, 71). In some instances this secondary apex of growth was not differentiated until the plant had attained a considerable size (figs. 67, 68, 69), but in others, again, it was differentiated early (fig. 65). In fig. 1 is shown a plant attached to its prothallus in which the main shoot had a very irregular and peculiar appearance, and at the base of

which the new apex of growth could be seen. In longitudinal section it was seen that the rounded protuberance at the base of the plant shown in fig. 68 was formed by a surface group of actively dividing meristematic cells (a single apical initial could not be traced), and that from this meristem a plerome strand connecting with the central strand of the plant was in process of formation (fig. 63). Also it was seen that two tracheides were leading out from the centre of the plant-axis towards the new apex. Thus we may say that the development of the new axis of growth is adventitious, and may compare it with the well-known adventitious origin in the epidermal and outer cortical cells of older rhizomes of groups of meristematic cells which are frequently to be observed either in a state of arrested development or about to develop into lateral buds. It must, however, be noted that whereas these lateral buds are not confined to any part of the rhizome, but appear in a quite haphazard manner, the secondary apex of growth in the young plantlet is always differentiated in the one position. Thus there is no root to be distinguished in the young plant of *Tmesipteris*, there being developed, both above and below the original foot, a rhizome identical in the two cases in appearance, function, and manner of growth.

A series of transverse sections through the foot of a young plant which consists of both primary and secondary rhizome portions—such, for example, as that given in fig. 72—shows that there is a continuous vascular strand throughout the whole rhizome, identical in structure in the two portions of the rhizome, and unbroken in the foot region. Before the secondary apex of growth is differentiated in the young plant the vascular strand inclines bodily into the foot. When the new apex is formed a plerome strand is differentiated from it, and it would appear that this joins on with the primary strand at the angle where the latter inclines into the foot. Possibly the first vascular elements in this secondary strand are actually formed from the angle of the primary strand in connection with the transport of food from the prothallus to the new apex. In fig. 63 is shown the stage at which the plerome strand of the secondary portion of the rhizome is in its earliest development, but vascular elements seem to be leading out to meet it from the point where the strand of the primary part of the rhizome leads down into the foot.

The growing apices of the young developing plantlets are whitish-grey in colour and more translucent than the rest of the rhizome, and are often slightly swollen. In this respect, and in the general appearance of the young rhizome, there is a certain similarity between detached portions of prothalli and of young plants. The fungal coils are present in the cortical cells of young plants which are still attached to their prothalli, but apparently the fungus does not spread from the prothallus to the plant, but the latter is early infected through its rhizoids. Several of the young rhizomes bore short swollen lateral shoots (fig. 72), clear or almost light-green in colour, and one frequently noticed on the rhizomes of both young and older plants points of meristematic activity. Besides this adventitious method of branching, the rhizome-apex may fork dichotomously (fig. 75). Sooner or later one or other of the main ends of the young rhizome grows upwards as an erect aerial shoot, losing its rhizoids and decreasing in thickness in the transition region. The aerial shoot is at first whitish in colour and is quite devoid of both rhizoids and scale leaves, but at length its apex becomes green and gives rise to the first scale leaves (figs. 5, 73, 74). After a few of these scale leaves have been formed,

larger leaves of the characteristic form take their place. Both ends of the young rhizome may in some cases emerge from the humus as aerial stems (fig. 73). The actual apex of the young aerial shoots is slender and sharply conical (figs. 5, 73, 74), and even in surface view under a low power of the microscope the single apical cell can be seen. In longitudinal section the apical cell and the order of segments cut off from it is almost diagrammatically clear (fig. 77). The broader apex of young rhizomes also shows a single apical cell (fig. 76). In several instances young plants of a considerable size, showing differentiation into both subterranean and aerial portion, were found still attached to their prothalli, the latter being in some cases firm and healthy (figs. 5, 73), and in others old and withered (figs. 9, 10).

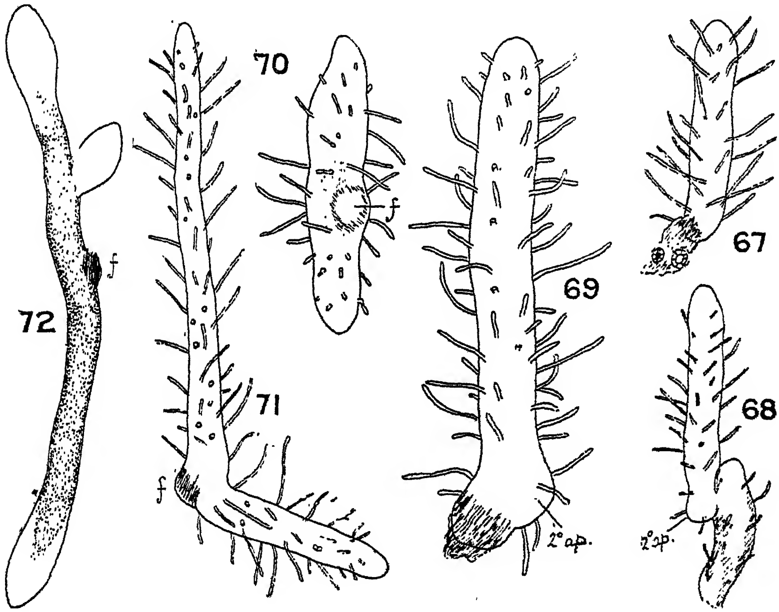


FIG. 67.—Young detached plantlet, showing fragment of prothallial tissue attached to foot; secondary apex of growth not yet developed. × 8.
FIG. 68.—Young plantlet attached to prothallus, showing secondary apex of growth. × 5.
FIG. 69.—Young detached plantlet, showing foot and secondary apex of growth. × 7.
FIG. 70.—Young detached plantlet, showing foot and also primary and secondary apices of growth on either side of foot. The two apices are not inclined to one another at an angle. × 8.
FIG. 71.—Young detached plantlet, showing foot and also primary and secondary regions of rhizome on either side of the foot. × 6.
FIG. 72.—Young developing complete plant, showing foot and also lateral bud; the latter and the two apices are swollen. × 4.

DEVELOPMENT OF THE VASCULAR ANATOMY.

The anatomy and morphology of the adult plant of *Tmesipteris* has already fairly recently been described by Miss Sykes (1908), so that there is no need for me to go over this ground again. Miss Sykes's material came from New Zealand, and she notes that it comprised two forms which

had previously been separated by some writers as two species—viz., as *T. tannensis* and *T. lanceolata*. She gives figures of the aerial stems of these two forms. In the section in the present paper which deals with "Occurrence and Habit" I noted the fact of these two forms, and indicated that the prothalli and young plants which I had obtained belonged to the form which grew to the greater size and had the more pendulous and flaccid habit and possessed the larger leaves. This is the form referred to by Miss Sykes as *T. lanceolata*. Cheeseman (1906) does not recognize more than the one species in New Zealand, to which he gives the general name *T. tannensis*, although in a note he adds, "By some authors it is split up into three or four, distinguished mainly by the shape of the apex

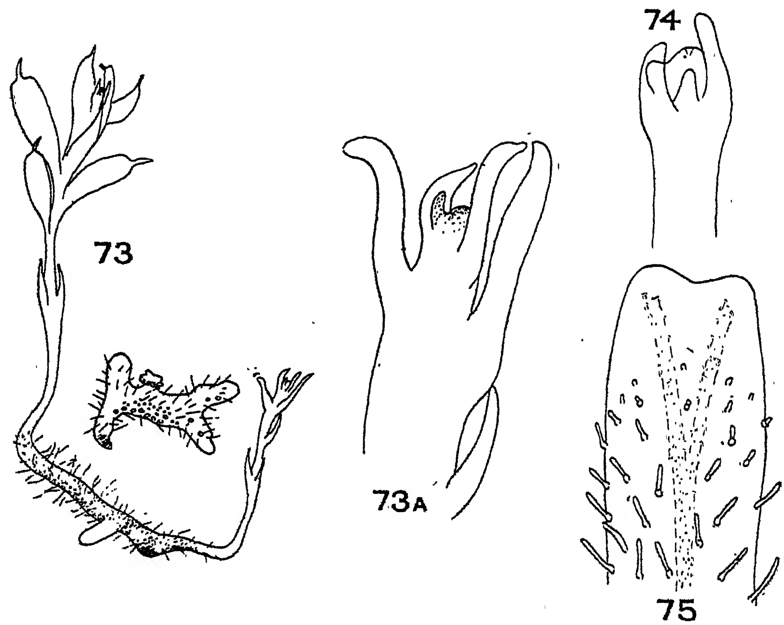


FIG 73.—Complete young plant, showing parent prothallus, foot, lateral bud, and also both ends of rhizome developed into aerial stems. × 2.
FIG. 73A.—Apex of smaller aerial stem shown in fig. 73. × 9.
FIG. 74.—Apex of a young aerial stem, showing initiation of leaf-formation. × 9.
FIG. 75.—Apex of rhizome of young plant, showing dichotomy. × 10.

of the leaf (which I find to be variable even in the same individual) and by certain histological details, the constancy of which has yet to be established." I have not had access to the papers referred to by both Miss Sykes and Mr. Cheeseman as setting forth the exact morphological and histological details on which the distinction is drawn between the different forms of *Tmesipteris*, so cannot refer particularly to them. However, I shall be noting in this section of my paper certain details in the stem-structure of the two forms referred to above.

Having an abundance of young plants of *Tmesipteris* of the form *T. lanceolata* of all stages of growth, I made a study of the development of the vascular cylinder of both the rhizome and the aerial shoot. I have no serial sections of the youngest plantlets, such as those shown in figs. 64

and 65, in which the differentiation of vascular tissue between the shoot-apex and the foot would be in its earliest stages. Transverse sections of plantlets of the same age as that shown in fig. 68 are given in figs. 78, 79, and 80 There is a slight central strand consisting of, in the one case, one, and, in the other, two, narrow scalariform tracheides placed more or less collaterally with a group of darkly-staining phloem elements.

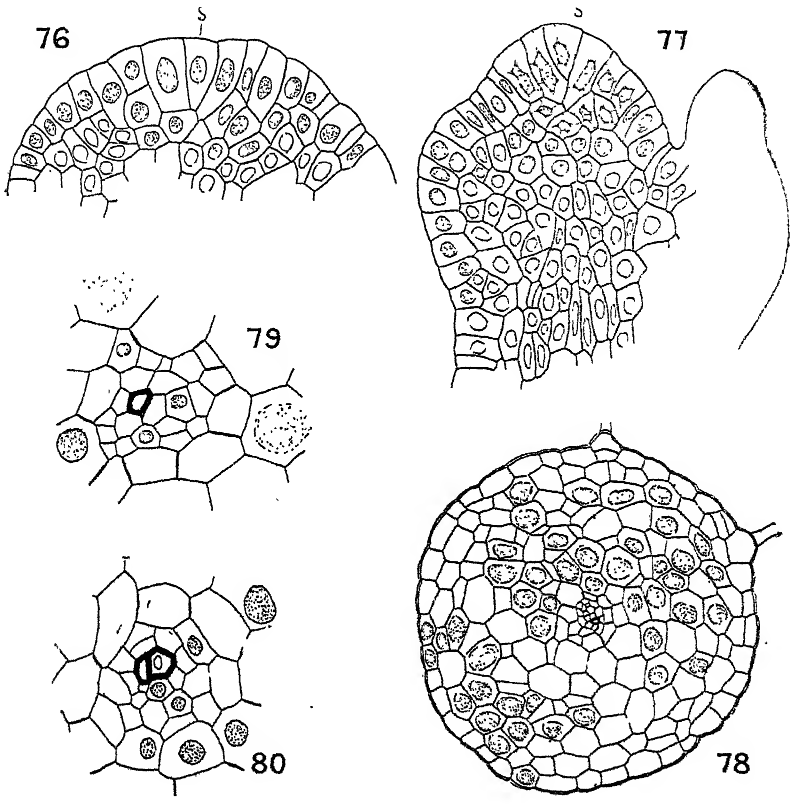


FIG. 76.—Longitudinal section of apex of rhizome of young plant shown in fig. 5, showing single apical cell. × 140.
FIG 77.—Longitudinal section of apex of aerial stem of young plant shown in fig. 5, showing single apical cell. × 140.
FIG. 78.—Transverse section of stem of young plant similar to those shown in figs. 66–68. × 50.
FIG. 79.—Transverse section of stele of stem shown in fig. 78. × 200.
FIG. 80.—Transverse section of stem stele of another young plant. × 200.

There is an endodermis in which the characteristic radial markings are clear. The cortex is uniformly parenchymatous and harbours the fungal coils more especially in its middle zone, whilst the epidermis is cuticularized and individual epidermal cells are prolonged into rhizoids. Longitudinal sections of a young prothallial plantlet similar to that shown in fig. 68 revealed the fact that the vascular strand of the shoot curved bodily round at the base of the plant into the foot, where it ended blindly. From

sections of the plant and prothallus shown in fig. 66 it was clear that even at this early stage the peculiar brown deposit referred to by other writers in their studies of the mature rhizome of *Tmesipteris* and *Psilotum* is present in its first beginnings in the innermost layer of cortical cells. The rhizome and the aerial stem of the plant shown in fig. 5 were similar to each other in their vascular structure, three or four xylem elements lying more or less collateral with a group of phloem. The fungal element was present in the cortical cells of the rhizome but not of the aerial stem, and in

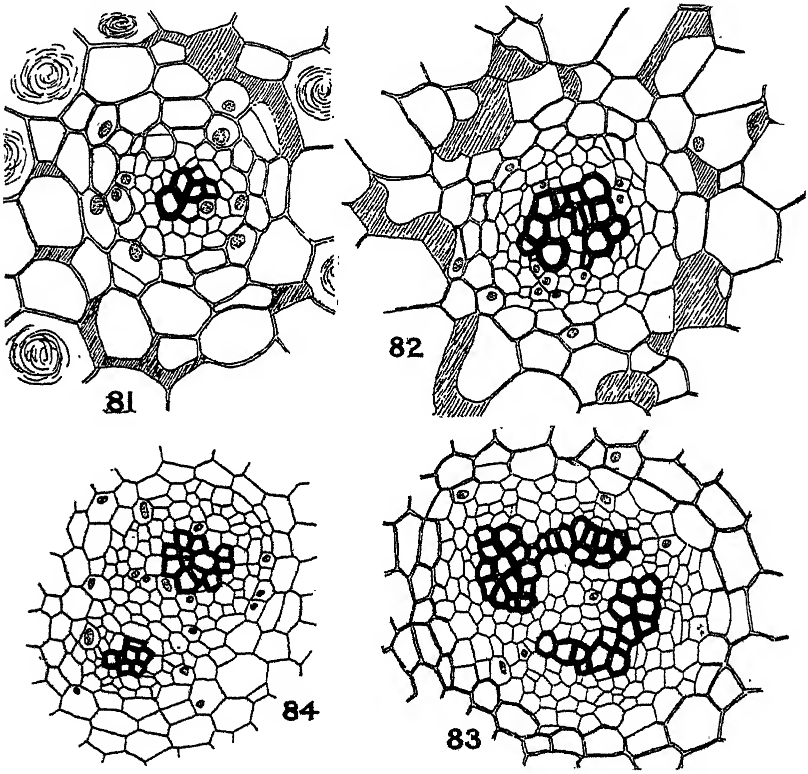


FIG. 81.—Transverse section of stele of rhizome of young plant. × 160.
FIG. 82.—Transverse section of stele of rhizome of medium-grown plant. × 125.
FIG. 83.—Transverse section of stele of large rhizome of plant shown in Plate I. × 125.
FIG. 84.—Transverse section of stele of aerial stem of young plant shown in fig. 85. × 125.

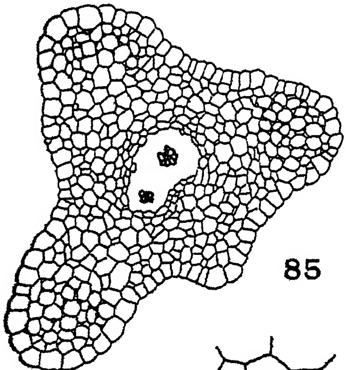
neither case was the brown deposit to be seen. The endodermis was here not so clearly defined as in younger plants. A transverse section of the rhizome of a slightly older plantlet is given in fig. 81, and shows that here the single group of xylem elements is placed centrally in the midst of the darkly-staining phloem, the metaxylem having been formed centripetally. Immediately surrounding the phloem are one or two layers of larger cells, probably to be identified as pericycle and endodermis, whilst the cortex is slightly collenchymatous and its innermost layer shows marked evidence of the brown deposit. The middle cortical zone contains the mycorhizal coils, while the outer surface and the rhizoids had the

same brown coloration as has the peculiar deposit already referred to. In the vascular cylinder of a medium-grown rhizome, sectioned at some distance behind the apex, there is a tendency for thin-walled elements to invaginate the centrally placed group of xylem (fig. 82), and in some sections it was seen that it had separated it into two groups. In these rhizomes the brown deposit can be seen in all stages of formation, and it may be detected also in individual cells in the middle cortex, while the fungal coils have almost disappeared from the cortical cells. In fig. 83 is shown the vascular cylinder of the largest ground-growing rhizomes of the form *T. lanceolata* obtained by me in Stewart Island. Here the xylem is definitely split up into two main curving plates more or less surrounding a central group of thin-walled elements. The comparison of a number of sections showed that the configuration of these xylem groups was constantly changing, sometimes two adjacent ends of the groups joining, and at other times one or both of the two main groups subdividing so that the number became three or four. It would seem, then, from a comparative study of the rhizomes of plants of different ages, that along with the increase in number of xylem elements in the central cylinder there is a diminishing disposition on their part to cohere in one group, so that the original monarch condition becomes lost and the xylem is disposed in separate plates or groups in the midst of the phloem, the tendency being in the oldest rhizomes for these groups to be arranged more or less in the form of a ring surrounding a central group of thin-walled (so-called "pith") elements. It must be noted that this alteration in the xylem-grouping is in no wise occasioned by any branching of the stele. In these very large humus-growing rhizomes also it was seen that the fungal element was almost entirely absent from the cortical cells, nor did the latter show any signs of thickening at their angles.

The development in size and configuration of the rhizome stele corresponds in a general way to what Miss Sykes (1908) has described in the gradual differentiation of the stele behind the growing apex of the mature rhizome, except that she refers the splitting-up of the original single xylem group into two or more groups only to the transition region between rhizome and aerial stem. Her material probably did not include such large-sized rhizomes as those examined by me.

As I have stated above, in the youngest plantlets which show differentiation into both aerial stem and underground rhizome the vascular cylinder is identical in configuration in both. The stele is monarch, the xylem group containing from two to six scalariform elements. In aerial stems of slightly older plants, however, there is a marked change, the characteristic structure of the adult aerial stem, with its separate mesarch xylem strands, beginning to manifest itself. A transverse section of such a young stem shows the pressure of large adherent leaf-bases forming conspicuous angles to the section (fig. 85), the cortical tissue in the angles containing abundant air-spaces. In the central cylinder there are two groups of xylem, obviously mesarch, on the outer side of each of which is phloem, whilst the tissue separating the two groups has the appearance of ordinary parenchymatous cells (fig. 84). I could not identify endodermis or pericycle. There are in young stems of this age no leaf-traces, the leaves as yet being no more than scale leaves. There is, of course, as in all aerial stems, no fungus present. Again, in the aerial stems of still older plants there are to be seen three such separate groups of xylem (figs. 86 and 87) placed in the form of a triangle, the position of the xylem

groups corresponding to the leaf-bases. There is a very slight leaf-trace, consisting of a few narrow phloem-like elements with no xylem. The cortical cells are still thin-walled, but in some sections it is apparent that the phloem and the other parenchymatous elements in the central cylinder are beginning to show a slight thickening of their walls. Lastly, in figs. 88 and 89, are shown the steles of the aerial stems of more mature plants, in which there are five mesarch groups of xylem. In the largest aerial stems of all there is a tendency for neighbouring groups of xylem temporarily to join together, thus forming curving plates (fig. 89). In these oldest stems the phloem and the "pith" elements are partly



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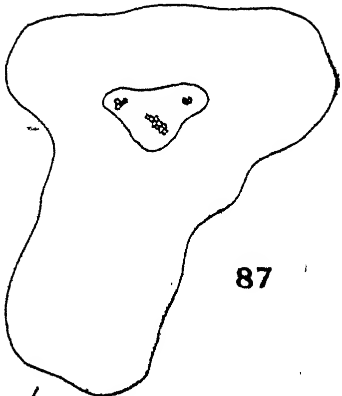

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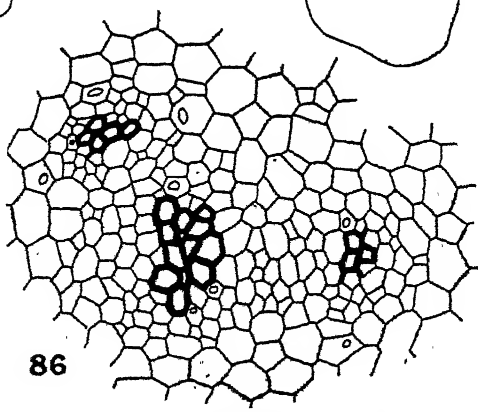

86

FIG. 85.—Transverse section of aerial stem of young plant. $\times$ 46.
FIG. 86.—Transverse section of stele of aerial stem of young plant shown in fig. 87. $\times$ 140.
FIG. 87.—Transverse section of aerial stem of young plant. $\times$ 46.

lignified, as has been described by Miss Sykes (1908, p. 70). In fig. 90 is shown a single xylem strand, illustrating its mesarch character and the lignified nature of the surrounding elements. The leaf-trace is collateral, and consists of two or three xylem elements and a group of phloem (fig. 89). I must remark again that the plants of various ages which I examined, and which are described above, all belonged to the particular form of *Tmesipteris* referred to as *T. lanceolata*. In none of the aerial stems of this form did I find the cortex collenchymatous, or the presence of the brown deposit in its innermost cells. This is in contrast with what Miss Sykes states in her paper (1908, p. 70), for she found

both these characters present in the aerial stems. I sectioned also some material, obtained from a tree-fern, which presented a very typical example

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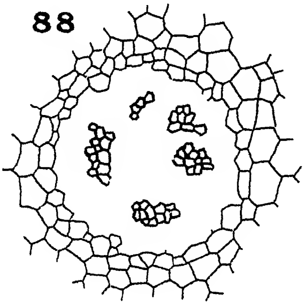

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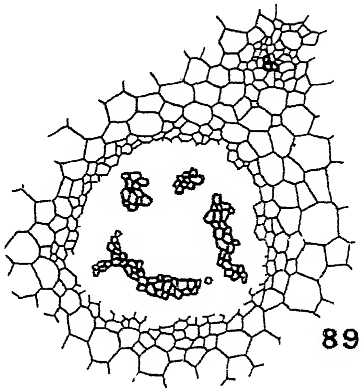

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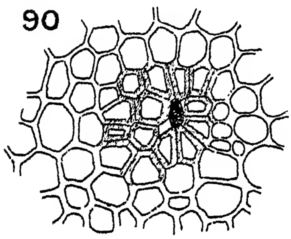

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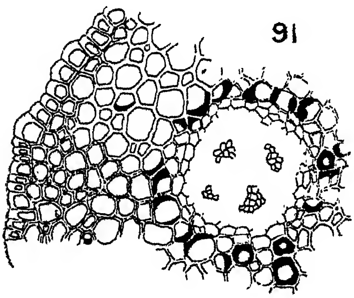

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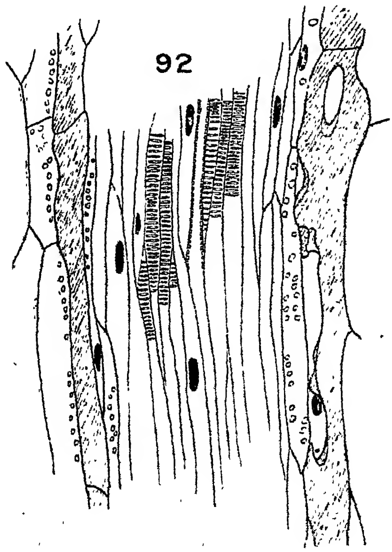

FIG. 88.—Transverse section of aerial stem of mature plant. × 60.
FIG. 89.—Transverse section of aerial stem of mature plant, showing coalescence of neighbouring xylem groups into bands, and also a leaf-trace. × 60.
FIG. 90.—Transverse section of single xylem group in stele of aerial stem of mature plant. × 175.
FIG. 91.—Transverse section of base of aerial stem of mature plant of *Tmesipteris tannensis* which showed characteristic short erect xerophytic habit, showing strongly lignified cortex and presence of brown deposit. × 50.
FIG. 92.—Longitudinal section of stele of rhizome of same material as that indicated under fig. 91, showing method of deposition of brown substance in inner cortical cells. × 70.

of the form illustrated by Miss Sykes as *T. tannensis*. The aerial stem was short and suberect and very compact in habit, and the rhizome firm and brittle. A transverse section taken towards the base of this particular

stem is shown in fig. 91, in which it will be seen that the cell-walls of the entire cortex are strongly thickened (taking both the safranin and the haematoxylin stain) and that the brown deposit is also present. In fig. 92 is shown the vascular cylinder of the same region of the stem in longitudinal section, in which there is a good example illustrated of the progressive method of deposit of the brown substance in the inner cortical cells. The conclusion I would draw is that whereas the general configuration of the vascular tissues is the same for both forms, *T. tannensis* and *T. lanceolata*, as regards both the rhizome and the aerial stem, yet there are certain less important but constant histological differences between them. The rhizome of *T. tannensis* does not attain as large a size as that of the loose-humus-growing *T. lanceolata*, and hence does not show the same extent of development of vascular tissues with the consequent splitting-up of the xylem into constantly changing groups. Also, in the drooping aerial stem of *T. lanceolata* there is an absence of the thickening of the walls of the cortical cells and of the formation of the brown deposit, both of which features are present in the more xerophytic stem of *T. tannensis*.

From the present study it would seem that there is no great difference between the stele of the rhizome and that of the aerial stem, and this one would expect, seeing that they are merely different regions of the plant-shoot, differing only in function. Any of the rhizome-branches are able to emerge from the surface of the humus and develop leaves. In the youngest plantlets the shoot is all rhizome, and one or both ends of it turn upwards and acquire the aerial habit. The rhizome portion functions largely probably as a storage organ, bearing rhizoids, harbouring an abundant mycorhiza, and showing the presence of starch in the cortical cells. The aerial stem shows an absence of all these characters, but the comparatively large leaves, with their strongly decurrent bases and the fertile structures, constitute its dominant feature. In the youngest plants the configuration of the vascular tissues is identical in both rhizome and aerial region. In both, as the number of vascular elements increases, there is manifested a disposition for the xylem to arrange itself in groups surrounding a central "pith," this being more marked and definite a feature in the aerial stems, probably on account of the influence of the leaf-trace system. In the aerial stems the xylem strands are characteristically mesarch, and Miss Sykes has shown that this is so also in those parts of the rhizome where the xylem is arranged in separate strands. In both there is a disposition for neighbouring xylem strands to coalesce to form curving plates of tissue surrounding the central pith as by a broken ring. Thus the nature of the full-grown stele throughout the *Tmesipteris* plant, and the manner of its development both at the apex of the mature rhizome and in the young plant, from the monarch or collateral condition, through the stages of diarch, triarch, and quadrarch to the ring-like condition, may be closely compared with the form and development of the stele in the adult plant of *Psilotum triquetrum* such as Miss Ford (1904) and Mr. Boodle (1904) have described it. In his paper Boodle traces the similarity between *Tmesipteris* and *Psilotum* with regard to the stem-anatomy, and shows that one great point of difference between them—viz., the mesarch structure of the xylem strands in the aerial stems of the former—to a certain extent breaks down owing to his discovery of isolated instances of mesarch structure in the lower regions of the aerial stem of *Psilotum*.

In view of the fact that Boodle and others have found secondary xylem in the transition region of the stem of *Psilotum*, I closely examined the stems of *Tmesipteris* from this point of view, but found there no traces of it. Also, it may be mentioned that I did not find any evidence of vegetative propagation in *Tmesipteris* corresponding to the formation of bulbils (Brutknospen) described by Solms-Laubach (summarized in Engler and Prantl, 1900, pp. 612–14) for *Psilotum*. The long aerial stems of *T. lanceolata* are sometimes branched, but I did not examine the branching of the stele. It is interesting to note that on the fertile stems the sporophylls occur in clearly defined regions corresponding to the habit so well known in *Lycopodium Selago*, and that on the longest stems as many as five or six such fertile regions may sometimes be observed separated from one another by sterile regions.

COMPARATIVE REMARKS.

It now remains for me to compare the prothallus and young plant of *Tmesipteris* as described in this paper with what has already been brought forward by other writers with regard to the gametophyte generation in the Psilotaceae, and also to include in this comparative survey certain other pteridophytic types of prothallus.

Lang's prothallus (1904), which he has provisionally assigned to *Psilotum*, conforms to a type which certainly differs markedly from that of *Tmesipteris* as described by Lawson and in the present paper. The differentiation of the prothallus into vegetative and reproductive regions with the meristem located between them, the organization of fungal zones and their evident influence upon the form and structure of the prothallus, is in striking contrast to what has been described for *Tmesipteris*. This we would probably not have expected, considering the strong morphological and anatomical resemblances between the two genera with respect to the adult plant. And yet, after all, there is not much greater difference between Lang's prothallus and that of *Tmesipteris* than what there is between, for example, the subterranean and the epiphytic types of *Lycopodium* prothalli; and we have come to look upon the latter as being but different modifications of a common fundamental structure of *Lycopodium* prothallus. Lang notes that the prothallus described by him is "practically identical with [that of] *Lycopodium complanatum*" (1904, p. 576), and goes on to show that it would not be surprising if the prothallus of *Psilotum* were of the subterranean type, for it commonly grows as a terrestrial plant as well as an epiphyte. Apparently he did not obtain from this single prothallus any information with regard to the archegonium or embryo; but as regards the structure of the antheridium there is certainly a great difference between what he has described and what is now known in the case of the antheridium of *Tmesipteris*. However, there is nothing to be gained by drawing out any further this comparison, for Lawson (1917A, p. 786) states that he has discovered "a single specimen of a structure that he believes to be the prothallus of *Psilotum* . . . [and that this] bears no resemblance to the supposed prothallus described by Lang." In a later paper he has described the prothallus of *Psilotum*, but this account I have not yet seen. The point that I wish to emphasize here is that in view of the remarkable diversities in form and structure known amongst the prothalli of the various species of *Lycopodium* we cannot regard the fact of the great difference in these respects between Lang's prothallus

and that of *Tmesipteris* as constituting a valid argument against the possibility of the former belonging to the Psilotaceae.

I must enter more into detail in comparing Lawson's observations on the prothallus of *Tmesipteris* with my own, because although it will be clear that they correspond in many particulars, yet it will be just as obvious that the two accounts differ in many other respects.

First of all, then, with regard to the similarities in the two accounts. The prothallus is shown in both to be subterranean and saprophytic in habit, of a characteristic brown colour, and covered with numerous long rhizoids. It is cylindrical in form, is not differentiated into reproductive and vegetative regions, and can branch. There is an endophytic fungus which is found in any part of the prothallus-body and is not localized in definite zones. The antheridia and archegonia are intermixed, and are distributed in large numbers over practically all parts of the surface of the prothallus. The two accounts of the structure of the mature sexual organs are closely similar. The embryo is carried on a distinct protuberance of the prothallial tissues, the result of localized meristematic activity in the cells of the latter keeping pace with the development of the embryo. The embryo shows a hypobasal and an epibasal portion, the latter being characterized by a peculiar development from its surface of lobes or protuberances. This general similarity in the two sets of prothalli and their essential organs might be sufficient to show that they both belong to the same order, Psilotaceae, or even also to the same genus, *Tmesipteris*.

But there are also some very striking differences between them which must be considered. To begin with, Lawson states that, "compared with the Lycopodiales and other Pteridophytes, the prothallus of *Tmesipteris* is small." His largest specimen measured only $\frac{1}{8}$ in. in length. My prothalli, except the very youngest, were very large compared with this, several of the largest being up to $\frac{5}{8}$ in. in length. The tissue of Lawson's prothalli "is extremely soft and fragile," and easily destroyed in the process of cleaning with a camel's-hair brush, whereas my prothalli are firm and solid and thick, and are very favourable objects for hand-sectioning in elder-pith. A small but striking point of difference lies in the fact that Lawson describes the rhizoids as characterictically twisted, but in my figures they are shown as perfectly straight. Lawson speaks of the endophytic fungus as being "more conspicuous in the surface cells and those near the surface," although it may extend into the very interior of the prothallus. I found that it was only in the oldest and lowest regions of the prothallus that the fungus inhabited the epidermal cells and those of the cortex immediately underlying it, but that it was uniformly present throughout the prothallus-body (except, of course, at the growing apices) in the more centrally placed cells. A comparison of figs. 1, 2, and 3 in Lawson's paper with any of those in mine which show the complete prothallus will reveal a noticeable difference in the fact that in the latter cases there is always a bluntly rounded apex to each branch of the prothallus, the growing apices usually taking the form of a swollen head, whereas in the former the ends of the branches are shown (if not broken) as pointed structures. It will be noticed that these differences between the two accounts relate entirely to the external form of the prothallus and the disposition of the fungal element. The appearance and structure of the mature sexual organs is identical in both accounts. I must here point out that the archegonia as seen and figured by Lawson, and described by him as being very simple and peculiar, are only the old organs which, as has been shown in the present paper, have lost the upper tiers of neck-cells.

If it were not for the fact that in Lawson's figures of the prothallus some of the pointed ends of the branches are shown as complete and unbroken, I would be inclined to think that his specimens were merely fragments of old prothalli and not complete ones. All the points of difference enumerated above seem to point to this; and there is another fact which bears upon the same point—viz., that in none of the prothalli figured by him does he show a meristematic region. There is, however, quite another explanation of the differences between our prothalli, which is that whereas mine belong to the form sometimes spoken of as *T. lanceolata*, which, as I have shown, differs from the other form, *T. tannensis*, not only in general habit but also in certain histological details, Lawson speaks of his prothalli as those of *T. tannensis*. We have become so familiar with the fact of the manifold variations in the types of prothallus of the different species in the genus *Lycopodium*—new variations being found in almost each additional species discovered—that it is not unlikely that the prothalli of *Tmesipteris* as described in the two accounts will be found to be those of two different forms which have hitherto been grouped under the collective name *T. tannensis*. The fact that Lawson's prothalli were obtained by him almost singly from widely different localities and in different years indicates that they represent a constant type of prothallus.

The prothallus of *Tmesipteris* shows certain resemblances, such as its cylindrical, radially symmetrical, and more or less drawn-out form, its apical growth, and its branching, to certain other pteridophytic types of prothallus, such as those of the epiphytic Lycopodiaceae and Ophioglossaceae and *Helminthostachys*. But these resemblances are only what might be looked for in prothalli having the same epiphytic habit. Even with regard to these general characters the resemblance does not hold quite closely, whereas in the matter of other main features, such as the nature of the basal (or "primary tubercle") region, the distribution of the fungal element, and the differentiation of vegetative and reproductive regions in the prothallus, there are striking differences. Thus on a general sum of characters the prothallus of *Tmesipteris* stands apart from that of both the Ophioglossaceae and the Lycopodiaceae. Still less does it show any evidence of affinity to the prothallus of *Equisetum*. This conclusion is strengthened by a comparative study of the sexual organs, embryo, and young sporophyte. The antheridium is strongly projecting in a manner almost resembling that of the male organ of the leptosporangiate ferns, whereas that of the Ophioglossaceae and Lycopodiaceae is sunken. However, in the manner of its development it agrees with that of the two latter orders. The archegonium also is peculiar in that there is apparently no basal cell cut off in the young rudiment, and the form of the mature organ is very characteristic. It is not certain from which primary half of the young embryo the shoot and the foot respectively develop, or whether there is or is not a suspensor present. But the peculiar development of the foot into long haustoria-like processes, the total absence of a root, and the dominance of the shoot mark out the embryo of *Tmesipteris* as bearing very little resemblance to that of any other class of Pteridophytes. From the single embryo found by him in which three lobes were present on the lower half Lawson is inclined to interpret one of these lobes to be the rudiment of the root, ascribing the others to the foot. The fact that in older stages there are a large number of these lobes present, and that they are all similar in appearance, seems to me to indicate that they are nothing more than haustorial outgrowths; and this would also appear to be borne

out by the fact that the vascular strand of the shoot is in close connection with them. However, their early appearance in the young embryo is noteworthy. Lawson's embryo presents an interesting stage slightly older than those described in the present paper, but there is still a gap in the series which conceals the first differentiation of the young stem-apex, although such very young plantlets as those shown in figs. 61, 64, and 65 in the present paper seem to indicate that the shoot arises from the hypobasal portion of the embryo.

Scott (1900, p. 499) first pointed out the similarity between the sporophyll of the Psilotaceae and that of the Sphenophyllales, and repeated his statements more fully in the second edition of his *Studies* (1909, pp. 626–31). Thomas (1902) strengthened this idea by showing that the nature of the frequent abnormalities which occur in the sporophylls of both *Tmesipteris* and *Psilotum* bring those structures nearer still to those of certain of the Sphenophyllales and especially to that of *Cheirostrobus*. Miss Sykes (1908) has also supported this with additional evidence by her elucidation of the vascular structure of the sporophyll and synangium of *Tmesipteris*. Both Bower (1908) and Seward (1910, p. 14) have accepted the suggestion of the affinity of the modern Psilotaceae with the fossil Sphenophyllales.

A general similarity in vascular structure in the mature plants of *Tmesipteris* and *Psilotum* has been pointed out by various writers, and, as described in the present paper, the study of the development of the stele in both the rhizome and aerial stem of *Tmesipteris* helps to make the nature of this structure more clear. Scott (1900) noted the similarity between the stem-anatomy of the Psilotaceae and that of the Sphenophyllales, and Boodle (1904) has developed the idea and made it more marked still by the discovery of what he believes to be reduced secondary xylem in the subterranean parts of *Psilotum*.

There is no need for me to recapitulate here all the details concerned in this double correspondence between the Psilotaceae and the Sphenophyllales, for they have been thoroughly co-ordinated and analysed by most of those who have written recently on the subject, as, *e.g.*, Scott (1909), Sykes (1908), and Boodle (1904).

The peculiar features of the Psilotaceae are open to interpretation in any of the following three ways: They may be regarded as primitive, or as the result of reduction, or as being recent adaptations. This is so also, of course, in other pteridophytic groups, such as, for example, the Lycopodiaceae and the Equisetaceae, and an instructive parallel may be drawn between them and the Psilotaceae in this respect. Through our knowledge of the fossil plants of the Carboniferous and succeeding periods we have learned to look upon each of these two groups as being the modern representatives—mere remnants—of families which dominated the forest of the Palaeozoic age. The modern Lycopods and Equisetums do not show the presence of secondary wood (except in one known instance), and this may indicate either that they have lost it by reduction in their descent from large Carboniferous ancestors which possessed it, or that they are descended rather from humbler ancestors which existed side by side with the tree forms but which had never attained to secondary growth. The comparative study of the stem-stele in the modern Equisetums and the fossil Calamites reveals the presence of a primary structure common to both, so that the modern group in this particular, as also in external form and in the nature of the strobilus, is regarded as preserving primitive characters. The Lycopodiaceae may be read, according to two main

theories, either as a reduction series or as a progressive series, the simpler type of *Lycopodium*, such as *L. Selago*, being thus regarded either as very much reduced or as primitive in form. Certain features of the embryo and young plant, moreover, peculiar to a section of the Lycopodiaceae have been interpreted as primitive, and primitive not only for the Lycopodiaceae but for vascular plants generally. These are the protocorm and its surmounting protophylls. According to this theory, the protocorm is regarded as an indication of the way in which the primitive sporophyte first became independent of the gametophyte, and in pursuance of this idea the peculiar plant *Phylloglossum* has been spoken of as the most primitive form of Lycopod. However, a simpler explanation of the protocorm, and one widely accepted, is that it is merely a vegetative adaptation peculiar to one or perhaps two sections of the Lycopodiaceae, and that *Phylloglossum* has been derived from this particular section by reduction. Again, a third interpretation has been suggested, that the protocorm is a modified form of stem due to reduction, the basis of probability for the truth of this theory being the very large size attained by the Carboniferous ancestors of the Lycopodiums. These varying interpretations of the outstanding features of the Equisetaceae and the Lycopodiaceae are so well known that there is no need for me here to do more than merely indicate them or to cite the authorities. They are mentioned to serve as an analogy to the various interpretations which are possible in the case of the Psilotaceae. It will be necessary for me to discuss briefly the evidence in favour of regarding the Psilotaceae either as reduced forms or as retaining primitive characters.

Boodle (1904, p. 511) interprets the secondary tracheides found by him in certain parts of the stem of *Psilotum* as reduced secondary xylem, and considers that this feature reinforces the similiarity which has been traced between the Psilotaceae and the Sphenophyllales. He speaks of *Psilotum* and *Tmesipteris* as being reduced from "a common parent form, in which the aerial stem had a rayed mesarch xylem mass" (*ibid.*, p. 515) and which also showed secondary thickening. Such a stem, he says, would bear a strong resemblance to the axis of *Cheirostrobus;* but at the same time he is careful to point out that such a character as the presence of secondary xylem is too adaptive to be taken by itself as evidence of affinity (*ibid.*, p. 513, note 1). However, the presence of secondary xylem in the stem of *Psilotum*, he says, possesses certain significance in view of the fact that the fertile organ of the Psilotaceae finds its nearest parallel in that of the Sphenophyllales.

There is no doubt that the saprophytic habit of both *Psilotum* and *Tmesipteris*, the extreme reduction in the leaves of the former, and the presence in the rhizomes of a mycorhiza, may be taken as suggesting that their present form and structure is, at any rate partly, due to reduction. And, of course, the absence of a root organ may be regarded in the same way. Probably the most interesting point to be elucidated by a study of the life-history of the two members of this class is whether or not there is a rudimentary root organ to be traced in the embryo. Lawson (1917A, p. 793), from his study of the one embryo found by him, concludes that there is such a rudimentary root present. My own study of a number of embryos and of a fairly complete series of young plants has convinced me that there is not, but that the peculiar outgrowth of the absorbing region of the embryo which Lawson speaks of as a rudimentary root is only one of a large number of such outgrowths which are to be regarded

simply as haustorial protuberances of the surface cells of the foot. If there is no evidence forthcoming that the absence of the root is due to reduction, other than a certain degree of probability arising out of the present habit of the plants, coupled with the fact that in other isolated pteridophytic classes we seem to trace signs of reduction, we must ask, Is there anything to adduce in favour of the theory that the absence of a root in the Psilotaceae is a primitive feature? In this particular character the Psilotaceae stand alone amongst existing Pteridophytes. The fundamental differences between the various classes of Pteridophytes in the manner in which the root is differentiated in the embryo shows that those classes have been distinct from one another from a far-distant period, and accordingly if one of them shows the total absence of a root from its embryo this may quite conceivably be due to the preservation in the one particular line of descent of a primitive character of vascular plants. Such a theory will, of course, best be substantiated by direct evidence from the fossil record. Such evidence has lately been brought forward by Kidston and Lang in their account of the fossil plant *Rhynia Gwynne-Vaughani* (1917). It must suffice here for me to mention briefly those points in their paper which bear directly upon the present subject. The authors themselves state that they have reserved to a later paper their own discussion of the relation of their plant to the important questions concerning the differentiation of primitive Pteridophytes into stem, root, and leaf (*ibid.*, p. 775).

Rhynia Gwynne-Vaughani occurs in the Old Red Sandstone of Aberdeen, and is, as its investigators point out, "the most ancient land-plant of which the structure is at all fully known." Fortunately, the plant was preserved in large numbers as it grew, and Kidston and Lang have been able to elucidate fully its general habit of growth, external form, and structure. The plant was leafless and rootless, the branched cylindical stems being differentiated into underground rhizoid-bearing rhizomes and tapering aerial stems. Branching of the stem was by the dichotomous division of its apex, or more frequently by the formation on the stem of adventitious lateral branches. The vascular system of the plant consisted throughout of a simple cylindrical stele composed of a slender solid strand of tracheides, with no distinction of protoxylem and metaxylem, surrounded by a zone of phloem. The possession of these general characters leads Kidston and Lang to compare *Rhynia* with the existing Psilotales; but the presence of certain other characters, such as the total absence of leaves, the consistent simplicity of the stele, and especially the single large sporangia borne terminally on short stalks, has decided them to recognize a new pteridophytic class (to which they propose to give the name "Psilophytales") somewhat resembling the modern class Psilotales, and embracing with *Rhynia* certain Devonian plant fossils. The authors note that the comparison which they institute between *Rhynia* and the Psilotaceae "would lead us to regard the Psilotaceae as having preserved many primitive characters, and not as reduced. On this view the Psilotaceae would be the little-modified survivors in the existing flora of a type of plant that existed in early geological times, the most fully known example of which is now *Rhynia Gwynne-Vaughani*. It does not follow, however, that a direct line of descent is to be drawn between *Rhynia* and the Psilotaceae as we know them" (*ibid.*, p. 776).

It might, of course, with some reason be argued that the simple morphological nature of *Rhynia* was due to reduction; but, all things considered, it is more likely that the characters of this ancient plant are primitive

rather than reduced. The account given in the present paper of the life-history of *Tmesipteris* lends weight to Kidston and Lang's suggestion that the Psilotaceae, on account of their remarkable resemblance to *Rhynia*, are to be regarded as possessing primitive characters. The structure of the sexual organs, of the embryo, and of the young plant of *Tmesipteris* confirm the idea that the Psilotaceae should be removed from all other existing classes of Pteridophytes. The structure and form of the prothallus is also peculiar, but probably the gametophyte generation is always too adaptive to form the basis for much generalization. The simple stele found throughout the young plant of *Tmesipteris* in both rhizome and aerial stem resembles that of the Psilophytales. The theory that the mature plant of the Psilotaceae, as regards both its more complete vascular anatomy and also the nature of its sporophylls, finds in the Sphenophyllales its nêarest resemblances is quite compatible with the belief that in other respects the Psilotaceae have preserved the same primitive characters as are exemplified in *Rhynia*.

Just what is the degree of relationship between the Psilotaceae and these groups of fossil Pteridophytes is still, of course, far from clear. But this much, at any rate, may be said: that we have learned to look for the nearest relationships of this peculiar modern class of plants in the fossil record, just as has been done in the case of the Lycopodiums and Equisetums; and that while undoubtedly certain outstanding characters in the case of each of these modern remnants of once flourishing and important groups are best interpreted as reduced or even as adaptive, others, again, must be regarded as primitive, for they may be directly compared with corresponding characters in fossil plants.

POSTSCRIPT.

At the same time that the proofs of this paper were returned to me from the printer for a second revision Professor A. A. Lawson's second account of the prothallus of *Tmesipteris* (Lawson, 1917B) was kindly sent to me by its author, so that I am able to give in the form of an appendix a short comparison of his corrected results with mine.

My own account of the prothallus of *Tmesipteris* as given above corresponds more closely with that given by Lawson in his second paper than in his first. Since writing his preliminary account Lawson found a large number of prothalli, a certain proportion of which would be more or less complete, at any rate as regards their growing apices. One of these is figured by him (fig. 1). This prothallus shows a close resemblance to those figured in the present paper. Certain differences are due to the fact that Lawson's prothalli occurred terrestrially in a sandy soil, whereas mine were found amongst the tangle of aerial rootlets on tree-fern stems where the humus was scanty. More important differences to be noted are that Lawson does not describe or figure the first-formed tapering region of the prothallus: he describes the branching as irregular, whereas I have shown that it takes place normally according to a regular sequence of dichotomies; and the growing apices of his prothalli are not swollen, as were most of mine; also, my prothalli are stouter and more strongly grown. Otherwise, it seems to be clear from our two accounts that our prothalli are identical in nature. My account of the mature archegonia and antheridia corresponds also with that given by Lawson in his second paper. He there corrects his previous account of the mature archegonium, and shows, as I also have pointed out above, that there is a straight

projecting neck of four tiers of cells, which in most cases in the mature organ falls off almost level with the surface of the prothallus. In figs. 7 and 8 he shows two stages in the development of the antheridium. He gives no account of the embryo in this second paper, but leaves this subject for a still further communication.

In the same paper Professor Lawson describes and figures the prothallus and sexual organs of *Psilotum*. Here again his description is based upon ample material. There is no need for me to go into any detail other than to notice that Lawson draws attention to the remarkably close similarity between the prothalli and sexual organs of the two genera. This similarity in the matter of the gametophyte generation bears witness to the very near affinity of *Psilotum* with *Tmesipteris*, and serves also to draw our attention to the fact of the essential similarity in the stelar anatomy of the sporophyte. Lawson notes that the prothallus of *Psilotum* as described by him differs wholly from that which Lang provisionally assigned to *Psilotum*.

I have not seen Darnell-Smith's paper on the gametophyte of *Psilotum* (*Trans. Roy. Soc. Edin.*, vol. 52, 1917), quoted by Professor Lawson, in which he gives his observations on the germination of the spore, so cannot compare what he there says concerning the first-formed part of the prothallus with what I have described in the present paper in various well-grown prothalli with regard to the same.

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ART. II.—*The Resistance to the Flow of Water through Pipes.*

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[*Read before the Technological Section of the Wellington Philosophical Society, 7th July, 1917; received by Editors, 31st December, 1917; issued separately, 24th May, 1918.*]

INTRODUCTORY.

IN a previous contribution to this subject communicated to the Philosophical Society, and printed in the *Transactions of the New Zealand Institute*,* an attempt was made to determine the limits between which the resistance to the flow of water in a turbulent state is found to vary, first, for riveted steel pipes, and, secondly, for wood-stave pipes. This was done by plotting all the experimental determinations of loss of head which are on record and afterwards enveloping the observations as a whole by curves, the form of which was deduced from analogy with the ascertained law of resistance to flow through smooth pipes. In the present contribution an attempt is made to analyse the effect of different surfaces more in detail and to extend the study of the subject. The principle herein employed has been applied by the author to the observations upon the resistance to the flow of water in open channels, and the results communicated to the New Zealand Society of Civil Engineers.†

It is well known that the flow of water or any fluid assumes two different modes, the one in which the flow is linear and known as stream-line or viscous motion, and the other in which the flow is non-linear or sinuous, the flow being otherwise described as eddying or turbulent. The two terms "linear" and "sinuous" describe the two states very well, and are used herein in the sense defined. Between the two states there is an unstable region below which the flow is linear and above which it is sinuous.

In the linear stage the relationship between the elements affecting the resistance to motion is simple in character, and in consequence the nature of the relationship was discovered by experiment at an early date and subsequently rationalized, and is expressed as follows:—

$$\frac{rs}{v^2} = a\left(\frac{\nu}{vd}\right) \quad \text{..........................} \quad (1)$$

where s is the hydraulic gradient, r the hydraulic mean depth, d the diameter of the pipe, v the mean velocity, ν the kinematic viscosity (*i.e.*, the viscosity divided by the density of the fluid), and a a constant. Here the resistance is expressed as a loss of head per unit length of pipe, as is customary in engineering practice, whilst the customary notation has also been adopted—viz., r and s for the hydraulic mean depth and hydraulic gradient respectively.

In the sinuous or eddying stage, on the other hand, the relation between the elements of resistance is evidently complex, and as a

* E. PARRY, Resistance to the Flow of Fluids through Pipes, *Trans. N.Z. Inst.*, vol. 48, pp. 481–89, 1916.

† E. PARRY, A Critical Discussion of the Subject of the Flow of Water in Pipes and Channels, with Special Reference to the Latter, *Proc. N.Z. Soc. Civil Engineers*, vol. 3, pp. 116–32, 1917.

consequence the efforts of experimenters to discover the nature of the relationship has been fruitless, and, as little or nothing is known of the transformation of energy within fluids in sinuous motion, a precise mathematical solution was impossible. It may, however, be deduced from certain dynamical principles that the resistance is some function of $\left(\frac{\nu}{vd}\right)$ provided that there is a proportionality between the dimensions of the eddies and of the cross-section of the pipe, leaving the form of the function to be determined by experiment.

The law of resistance, then, in its most general form, which applies to both states of motion, is expressed as follows :—

$$\frac{rs}{v^2} = \phi\left(\frac{\nu}{vd}\right) \qquad (2)$$

where ϕ stands for "function of" and the other symbols have the same significance as in equation (1). As already explained, the relation between the quantities in the linear state is a simple one, the left-hand expression in equation (2) being a simple linear function of the right hand.

As regards sinuous or turbulent flow, it was supposed at one time that the nature of the function was of the form

$$\frac{rs}{v^2} = a\left(\frac{\nu}{vd}\right)^n \qquad (3)$$

but it is now known that this form is defective, and that the range of observations upon which it was based was not wide enough to determine the true form; it was soon found that equation (3) did not fit the facts, and in consequence a modification of this was adopted in which ν was treated as a constant, and independent indices given to v and d, yielding a formula of the form

$$v = kr^x s^y \qquad (4)$$

where k, x are constants and r is the hydraulic mean depth numerically equal to $d/4$ for round pipe.

This formula is one of considerable flexibility, and of late the whole phenomenon of the flow of water in pipes has been analysed afresh and expressed in the form given in equation (4). Its adoption has not, however, contributed anything towards extending our knowledge of the subject, and it is much to be regretted that steps were not taken to extend the range of observations when equation (3) was found to be defective. This aspect of the question has been apparently overlooked.

Such a series of observations extending over a wide range was recently conducted in the National Physical Laboratory by Stanton and Pannell* upon oil, air, and water in smooth brass pipes. The diameters of the pipes used varied from 0·142 in. to 5 in., and the mean speed from a fraction of a foot to 20 ft. per second. These combined with other observations upon the flow of water in smooth pipes when plotted with $\frac{rs}{v^2}$ as ordinates and log. $\frac{vd}{\nu}$ as abscissae were found to be sufficiently near to enable a curve to be drawn through the mean which was fairly representative of the whole, despite the fact that the condition of geometric similarity was not observed in respect to the surface of the

* T. E. Stanton and J. R. Pannell, Similarity of Motion in Relation to the Surface Friction of Fluids, *Phil. Trans Roy. Soc.*, A, vol. 214, pp. 199–224, 1914.

pipes. According to Professor Lees,* the mean curve can be expressed in the form

$$\frac{rs}{v^2} = a\left(\frac{\nu}{vd}\right)^n + b \quad\text{.......................... (5)}$$

the values, the coefficients, and the index being as follows :—

$$a = 0{\cdot}00801\,;\ b = 0{\cdot}000028\,;\ n = 0{\cdot}35$$

all the quantities being in foot-pound units.

More recently Lander† carried out an extensive series of experiments upon the flow of water and steam at speeds varying from 1·91 ft. per second to 11·55 ft. per second through ordinary commercial drawn-steel pipe of 0·423 in. diameter, and upon plotting the values of $\frac{rs}{v^2}$ against log. $\frac{vd}{\nu}$ he finds than an equation of the form (5) satisfies the relation between them. He, however, obtains different values of the coefficient and of the indices, the values being

$$a = 0{\cdot}0202\,;\ b = 0{\cdot}0000622\,;\ n = 0{\cdot}44$$

all values being in foot-pound units.

It is evident on contemplating the two sets of experiments that an equation of the form given in (5) correctly expresses the relation between the quantities near enough for all practical purposes, and it remains to be seen how far the principle is applicable to larger diameters and rougher surfaces, and it is the purpose of this paper to test its applicability to cast-iron, riveted steel, and wood-stave pipes of such sizes and characteristics as are in common use in the arts.

Before proceeding further in the direction indicated it may be useful and interesting to compare the form of equation (5) with Chezy's formula, viz. :—

$$v = c\sqrt{rs} \quad\text{.............................. (6)}$$

where c is a coefficient and r the hyraulic mean depth. It will be seen that c can be expressed in the form

$$c = \frac{1}{\sqrt{a\left(\frac{\nu}{vd}\right)^n + b}} \quad\text{...................... (7)}$$

Comparing this with other well-known formulae for c, we have Prony's equation, viz. :—

$$c = \frac{1}{\sqrt{a\left(\frac{1}{v}\right) + b}}$$

whilst Darcy and Bazm's formula may be expressed as follows :—

$$c = \frac{1}{\sqrt{a\left(\frac{1}{d}\right) + b}}$$

Evidently the influence and value of v predominate in Prony's experiments, whilst the value of d predominated in Darcy's experiments ; and

* C. H. LEES, On the Flow of Viscous Fluids through Smooth Circular Pipes, *Proc. Roy. Soc.*, A, vol. 91, pp. 46–53, 1914.

† C. H. LANDER, Surface Friction : Experiments with Steam and Water in Pipes, *Proc. Roy. Soc.*, A, vol. 92, pp. 337–53, 1916.

it does not seem to have occurred to any one to combine the two and thereby obtain an approximation to equation (7).

Kutter's formula for c is too complicated for ready comparison, and, after all, what is required is not a formula for c, but a sufficient number of observations for each class of pipe to enable a curve to be drawn correlating $\frac{rs}{v^2}$ to $\frac{vd}{\nu}$. The precise form of the equation expressing the relationship is really only of academic interest.

Returning to equation (5), the results of the experiments on smooth pipe by Stanton and Pannell are plotted in figs. 1, 2, and 3, and indicated by the number 6, whilst the result of Lander's experiments on drawn-steel pipe is indicated by the number 10, the abscissae being values of log. $\frac{vd}{\nu}$ and the ordinates values of $\frac{rs}{v^2}$. In fig. 4 the same equations are plotted in terms of log. $\left(\frac{rs}{v^2} - b\right)$ and log. $\frac{vd}{\nu}$. Line 6 represents Stanton's experiments, and line 10 Lander's. These two lines converge at or near to a point 0, where the motion changes from linear to sinuous. Line 12 represents linear flow, and should be common to all pipes within limits. The convergence of these three lines indicates that the two pipes fulfil the condition as regards geometric similarity. The method of plotting adopted in fig. 4 affords a ready means of determining the characteristic of any description of surface, provided that the condition before mentioned is fulfilled, for it is only necessary to make one observation of the quantities involved and to join the point representing the observed value to the point 0 in order to determine the whole characteristic. There is one remarkable coincidence between Stanton's and Lander's results—viz., the ratio of a to b is the same in both; which suggests a possible relationship which would be most useful if it can be proved to have any dynamical significance, but no deduction can be made in the absence of such a proof.

In applying the principle involved in equation (2) to experiments upon large pipes we encounter several elements of uncertainty. One is that the temperature of the water has not, as a rule, been observed and recorded; but as the error involved in assuming a uniform temperature and applying it to all the experiments is considerably less than the error arising out of other disturbing factors, and probably less than the error of observation under the conditions prevailing during the experiments, the temperature error is of no great moment.

Another factor which affects the harmony of the results arises from the fact that large-diameter pipe lengths are shorter than small-diameter pipes, and that in consequence the joints are more frequent; and, as the joint is a disturbing element, a large pipe and a small pipe of the same material and surface—such, for instance, as cast iron—are not strictly comparable on account of the increase in the number of joints, and often also because of the different nature of the joint. There is also the possibility that in two experiments on pipes of the same size and material the joint of the one may be better made than that of the other, and greater care taken in aligning the pipes.

In the case of riveted steel pipes we have still other disturbing factors. The longitudinal joints may be lapped or butted. There may be one, two, or three longitudinal joints in the circumference The circumferential joints may be alternately in and out, or taper; in neither case is the diameter of the pipe uniform. In one case we have a larger diameter alternating with a smaller diameter by twice the thickness of metal, with

the plate at the joint alternately facing and not facing the stream; in the other case we have the plate or section tapering from a large end to a small end by twice the thickness of the plate, whilst none of the joints face the stream. There is further the disturbance arising out of the different thickness of plate used, and in comparing two riveted pipes of different diameter it will be realized that they are not similar in all respects unless the thickness of plate bears some proportion to the diameter. The same remarks apply generally to spirally riveted pipe.

The principle involved demands that for the same values of vd at the same temperature the same value of $\frac{rs}{v^2}$ shall be obtained; but unless the frequency of jointing and the nature of the joints is the same, and unless there is a proportionality between diameter, thickness of plate, and size of rivet, it cannot be expected that the principle can be strictly applied, or that it can be proved to be applicable at all unless the characteristics mentioned are taken into account.

In spite of the vast array of experiments upon pipes of different kinds, it will be found that few of them are of much assistance in the present investigation. The characteristics of the pipe are not always precisely defined. The experiments on any one set are usually not numerous enough, or, if numerous, do not cover a sufficient range. Those experiments that are at all suitable have been used in the present paper, and a study of the diagrams will afford an indication as to the scope which should be given to further experiments.

In addition to the disturbing factors arising out of the nature of the surface, and frequency and nature of the joints, the thickness of plate in riveted pipe, and riveting, there is evidently another disturbing element arising out of the elastic compression of the water and from the acceleration and retardation of the flow. Most of the available observations on large pipe have been obtained under working conditions, and subject to disturbances arising out of change in velocity of flow due to the operation of valves and governors. When a change in velocity of flow is made, a wave of alternate compression and expansion is set up which takes some time to die down, especially if the pipe is a long one, and it is quite possible to obtain widely conflicting results on the same pipe and for the same average flow, due to the operation of the various impulses that may be set up. Another possible source of irregularity is the occlusion of air in larger or smaller quantities due to fluctuations of pressure. This might affect the flow considerably at a given head, whilst the proximity of the gauge to a bend or to a discharge-opening has been found to vitiate the results. That some disturbances of the kind mentioned are at work will be quite evident on contemplating the graphs showing the results, to which attention will now be drawn.

CAST-IRON PIPE.

A very complete list of experiments on loss of head in cast-iron pipe will be found in Barnes's work, *Hydraulic Flow Reviewed*, including some particularly careful determinations by the said author himself, which fulfil all the requirements. The examples selected are taken from the publication mentioned. Four experiments by Darcy on clean, new, uncoated cast-iron pipes are represented by a, b, c, and k in fig. 1, the diameters varying from 0·2678 ft. to 1·6404 ft. The readings are erratic, and no conclusion can be drawn from them further than that the trend of the observations generally follows the curve for drawn-steel pipes. The remaining experiments are upon asphalted cast-iron pipes, either

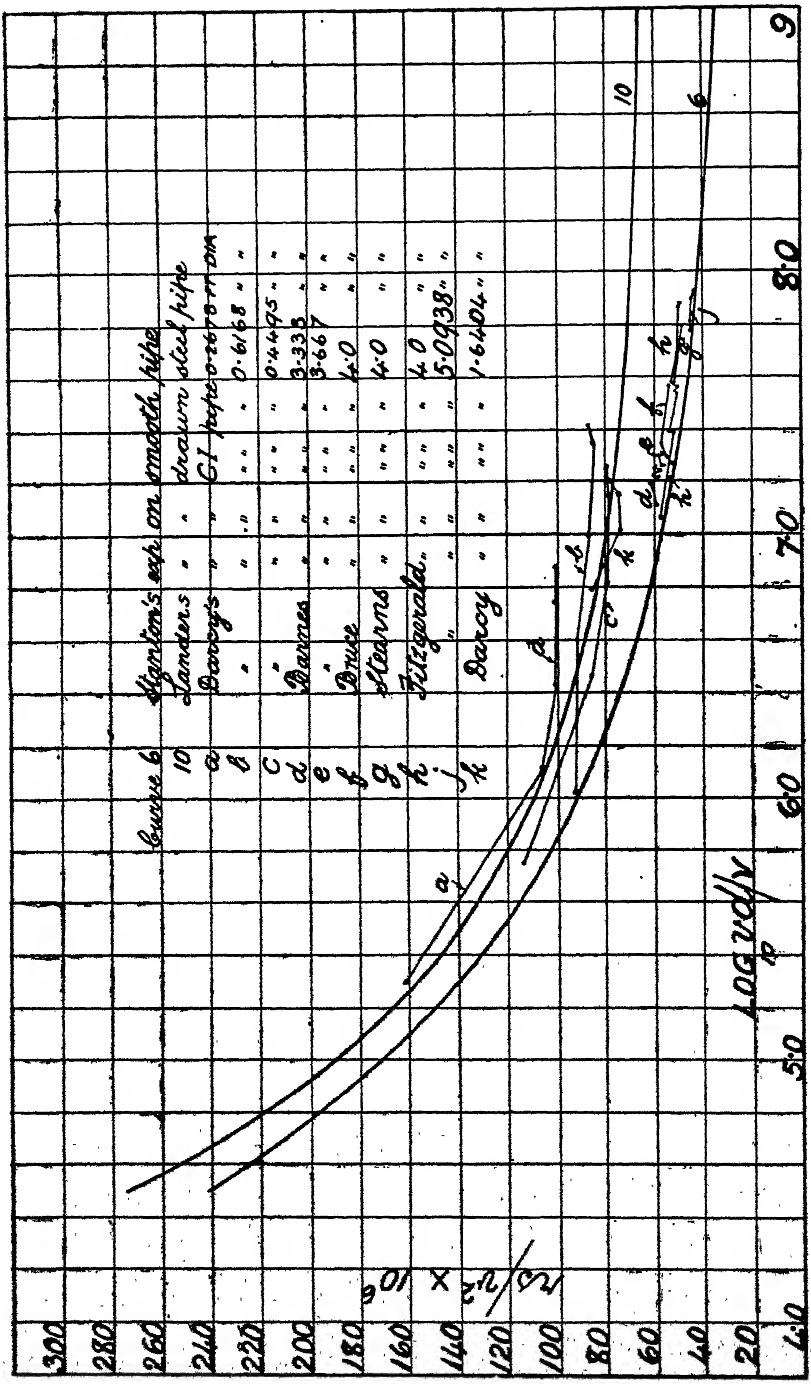

Curve 6 Stanton's exp on smooth pipe
10 Landers " " drawn steel pipe
a Darcy's " " CI pipe 0.2678 ft dia
b " " " " 0.6168 " "
c " " " " 0.4495 " "
d Barnes " " " 3.333 " "
e " " " " 3.667 " "
f Bruce " " " 4.0 " "
g Stearns " " " 4.0 " "
h Fitzgerald " " " 4.0 " "
j " " " " 5.0938 " "
k Darcy " " " 1.6404 " "
LOG vd/ν
S/v² × 10⁶
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
4.0
5.0
6.0
7.0
8.0
9

Fig. 1.

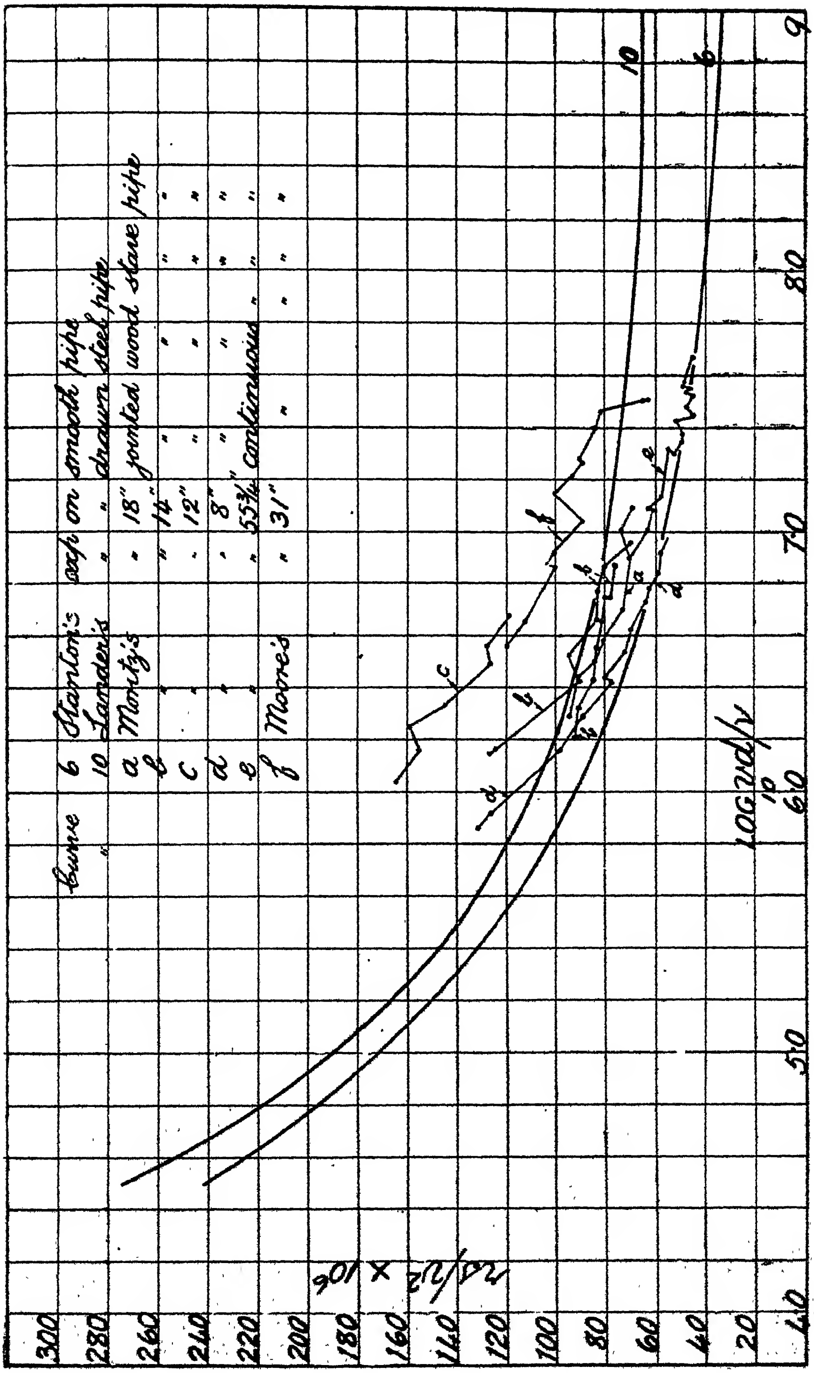

Curve 6 Stanton's exp on smooth pipe
" 10 Lander's " " drawn steel pipe
a Moritz's " 18" jointed wood stave pipe
b " " 14" " " " "
c " " 12" " " " "
d " " 8" " " " "
e " " 55¾" continuous " " "
f Moore's " 31" " " " "
LOG 10 vd/v
$2g\,d/v^2 \times 10^6$
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
4.0
5.0
6.0
7.0
8.0
9

FIG. 2.

newly cleaned or new. The diameters vary from 3·333 ft. to 5·0938 ft. by four different observers and six sets of observations. All the readings are remarkably close, and form a most valuable groundwork for further investigation. There are in all forty-six observations, all within the limit of observational errors, which could be represented by a single curve. All that is required in regard to this class of surface is a number of observations between the values of log. $\frac{vd}{\nu} = 6$ and log. $\frac{vd}{\nu} = 7$. Even as they stand a curve could be drawn with a fair amount of probability as to its correctness, as the observations follow the curve for brass tube; but, as the determination of the function is essentially an experimental one, the completion of the curve should be left to experiment.

Wood-stave Pipe.

Among the available experiments on wood-stave pipe, the most complete are those by Moritz.* Two classes of pipe are used—viz., jointed and continuous. The frequency of joints in the former case is, however, not specified. The observations on 18 in., 14 in., 12 in., 8 in. jointed pipe, and on a 55¾ in. by Moritz, and a 31 in. continuous by Moore, are plotted in fig. 2. It will be seen that in spite of the care exercised the results obtained on some of the pipes are somewhat erratic, due, no doubt, to the effect of impulses travelling through the water. The results as a whole are not consistent, and they do not lie near enough together to enable them to be represented to a single line, as the underlying principle demands. Nevertheless, they do not disprove the applicability of the principle, as the results are not consistent, whilst the difference between the observations on the same pipe are greater than the differences between the different pipes.

Riveted Steel Pipe.

Of the numerous experiments on riveted steel pipe, but two or three are suitable for the purpose of this paper. As a rule, the range is short and the readings erratic, whilst the particulars of the pipe are not complete. One of the most complete and extensive sets of observations is that made by Marx, Wing, and Hoskins† upon a pipe 6·04 ft. in diameter, the circular joints being butted, with a strap on the outside. The longitudinal joints are also butted, with a strap both inside and out. The length of pipe was 4,427 ft., with fourteen joints, and contained thirteen bends of 30 ft. radius and one of 40 ft. radius. The temperature of water is also recorded. The results are plotted in fig. 3 and marked *a*. On the same diagram are plotted experimental values by Herschell‡ on a 48 in. pipe marked *b* and a 36 in. pipe marked *c*. In each case the plates are ¼ in. thick and asphalted, built with alternate large and small cross-sections. All three sets of results are erratic, giving widely different values of $1/c^2$ for the same value of $\frac{vd}{\nu}$, and the readings on the same pipe differ more than the difference between the pipes, so that no conclusion can be drawn as to the complete applicability of the principle involved. All that can be

* E. A. Moritz, Experiments on the Flow of Water in Wood stave Pipes, *Trans. Am. Soc. Civ. Eng*, vol. 74, pp. 411–51, 1911.

† C. D. Marx, C. B. Wing, and L. M. Hoskins, Experiments on the Flow of Water in the Six-foot Steel and Wood Pipe Line of the Pioneer Electric Power Company at Ogden, Utah, Second Series, *Trans. Am. Soc. Civ. Eng.*, vol. 44, pp. 34–54, 1900.

‡ *One Hundred and Fifteen Experiments on the Carrying-capacity of Large Riveted Metal Conduits*, John Wiley and Sons, N.Y.

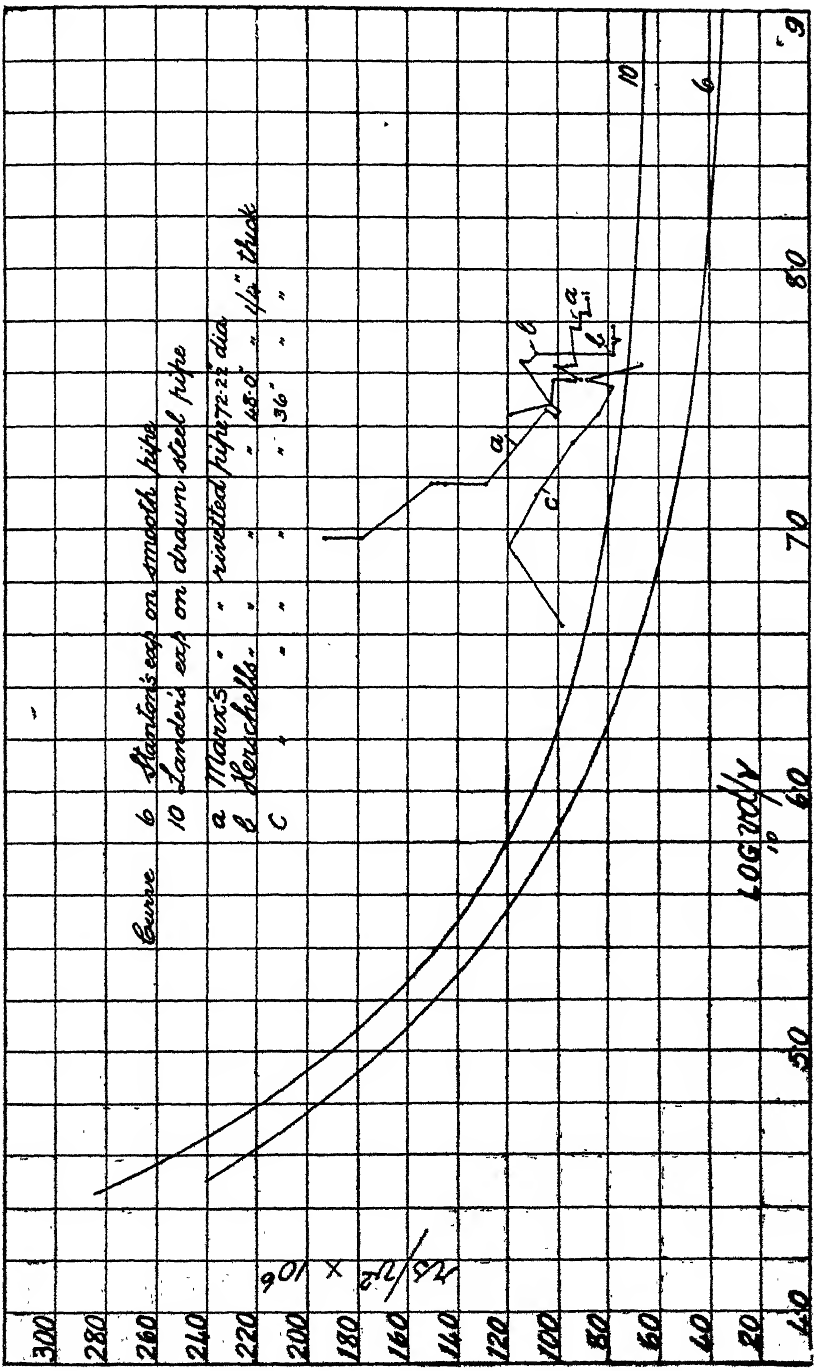
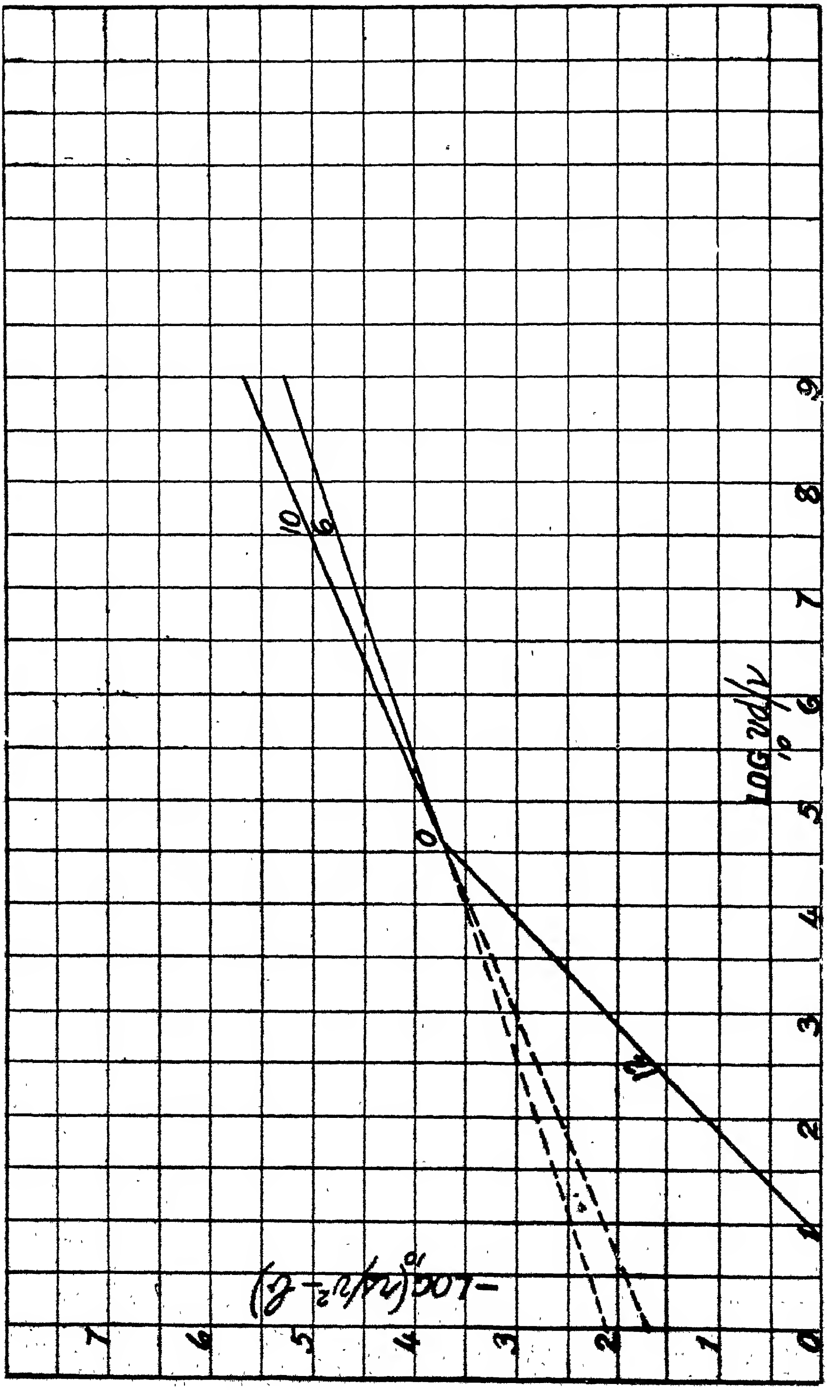

Curve 6 Stanton's exp on smooth pipe
10 Lander's exp on drawn steel pipe
a Marx's " riveted pipe 72·22" dia
b Herschell's " " 48·0" " 1/4" thick
c " " " 36" " "
LOG10 vd/ν
Rs/v²ρ × 10⁶

FIG. 3.



gathered from contemplating them is that their general trend indicates that the law of resistance can be expressed in the form of equation (5). The observations are, however, not consistent enough among themselves, and, if they were, they do not cover a sufficiently wide range to enable a curve expressing the relation between $\frac{rs}{v^2}$ and $\frac{vd}{\nu}$ to be drawn. There is evidently some disturbing factor at work which seems to have a greater effect at low values of the mean velocity and low friction heads.

COMPARISONS.

Comparing the results as a whole as plotted in figs. 1, 2, and 3, it may be said that their general trend is such as to conform with the law expressed in equation (5), and that they do not disprove the wide application of the principle to comprehend both large and small diameters, provided that the surface characteristics are similar.

As regards cast iron with clean, asphalted surfaces, the results of the more recent experiments are remarkably consistent and afford strong evidence in support of the theory, and it only requires a few more experiments in the proper region of exploration in order to enable a curve to be drawn for this class of surface.

As regards wood-stave pipe, the available results are not consistent, and new observations are required throughout the range.

As regards riveted steel pipes, none of the existing data are of much assistance, because of the wide variations between the readings. It is evident that in all the experiments some disturbing factors were operating in such a way as to vitiate the results, these making their influence felt more at low than at high velocities. More experiments extending over a wider range are required.

CONCLUSION.

The result of this investigation is not very conclusive. A beginning is, however, made in the direction of applying a principle which has been found to be applicable throughout a wide range of values of *vd*, and for widely different fluids, such as water, air, and steam, and extending it to large pipes in commercial use; and before further progress can be made more experiments are required on pipes of different diameters and different surface characteristics, selected with a view to extending the range of observations already obtained.

Whether or not this theory is applicable under all conditions, there is considerable advantage to be derived from plotting the results of observations against $\frac{vd}{\nu}$, as by this means one is able to exercise a far greater degree of judgment in selecting a probable value of *c* than by studying all the literature on the subject which exists, and the method is to be recommended on this account.

Readers are referred to a previous paper,* printed in the *Transactions of the New Zealand Institute*, for a diagram representing the coefficient of viscosity and the coefficient of kinematic viscosity of water at different temperatures, and also a diagram showing the relation between the values of log. $\frac{vd}{\nu}$ and *vd* for water at temperatures 0, 10, 20, and 30 degrees centigrade, the use of which will facilitate the manipulation of the diagrams presented in this paper.

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* E. PARRY, Resistance to the Flow of Fluids through Pipes, *Trans. N.Z. Inst.*, vol. 48, pp. 487–88, 1916.

Art. III.—*Revision of the Cirripedia of New Zealand.*

By L. S. Jennings, B.A., M.Sc.

Communicated by Dr. Charles Chilton.

[*Read before the Philosophical Institute of Canterbury, 5th December, 1917; received by Editors, 31st December, 1917; issued separately, 24th May, 1918.*]

Introductory Note.

The late Captain L. S. Jennings commenced the study of the New Zealand Cirripedia, a group of animals that had received very little attention from local naturalists, in 1910, and, becoming greatly interested in the subject, he continued his observations with much enthusiasm and great thoroughness, and hoped to be able to prepare a comprehensive paper dealing with the whole group. In 1915 he published a paper on the "Pedunculate Cirripedia of New Zealand and Neighbouring Islands" (*Trans. N.Z. Inst.*, vol. 47, p. 285). In this he gave a revised list of the species known to occur in the New Zealand region, established a new variety of *Lepas anatifera* Linn., and gave a critical discussion of the specific characters of *Lepas anatifera* Linn. and of the New Zealand species *Pollicipes*. He had nearly completed his examination of the sessile Cirripedia when he left for the front, and before his departure he gave into my charge all his specimens and manuscript notes. Though nearly all the essential work of identifying the species had been done, the manuscript was not arranged in a form suitable for publication. Mrs. Jennings has carefully gone over the collection, under my supervision, and has put the notes in order for publication. The paper contains a list of the New Zealand species examined by Captain Jennings, with localities, &c., of the different species.

References have been added to Pilsbry's "Sessile Barnacles (Cirripedia) contained in the Collections of the U.S. National Museum" (1916*), and to Borradaile's "Report on the Cirripedia of the 'Terra Nova' Antarctic Expedition" (1916 and 1917)—works which Captain Jennings had no opportunity of seeing.

In the list given below only those species are included which had been examined by Captain Jennings. Additional species are recorded from New Zealand by Hutton (1879, p. 330), Filhol (1885, p. 485), and Borradaile (1916, p. 128).

Those references only have been given which appear necessary for New Zealand workers.

The collection has been named and arranged in order, and is stored in the Biological Laboratory of Canterbury College. It contains a few specimens added after Captain Jennings left New Zealand, mainly from the collections of Mr. W. R. B. Oliver.

Captain Jennings was killed in action in France on the 15th September, 1916. By his death New Zealand was deprived of one of the most promising of the younger generation of workers in science.

Chas. Chilton.

* The references are made by the year of publication to the bibliographical list on p. 63.

Family LEPADIDAE.

Lepas anatifera Linnaeus.

Lepas anatifera Linnaeus, 1758, *Systema Naturae*, 10th ed., p. 668; Darwin, 1851, p. 73; Gruvel, 1905, p. 108; Pilsbry, 1907, p. 79; Chilton, 1911A, p. 571; L. S. Jennings, 1915, pp. 285, 288, figs. 1 (*a*, *b*, *c*), 2.

Specific Diagnosis.—" Valves smooth, or delicately striated. Right-hand scutum alone furnished with internal umbonal tooth: uppermost part of peduncle dark-coloured. Filaments, two on each side." (Darwin.)

Var. (*a*). " Scuta and terga with one or more diagonal lines of dark greenish-brown, square, slightly depressed marks." (Darwin.)

Var. (*b*). " Carina strongly barbed." (Darwin.)

Var. (*c*).* " No trace of an umbonal tooth on either scutum. The carina is not barbed and square patches on the capitulum are not visible." (Jennings.)

Localities.—General type: Sunday Island, Kermadecs (Bell and W. R. B. Oliver). Locality unknown—Specimens in Canterbury Museum.

Var. (*b*): Sunday Island, Kermadecs (W. R. B. Oliver).

Var. (*c*): Chatham Islands (Miss S. D. Shand); hull of " Terra Nova," Lyttelton (C. Chilton); Waitakerei River, washed up on beach (W. R. B. Oliver).

Lepas hillii Leach.

Pentalasmis hillii Leach, 1818, *Tuckey's Congo Exped.*, p. 413. *Lepas hillii* Darwin, 1851, p. 77, pl. i, fig. 2; Gruvel, 1905, p. 110, figs. 124, 125; Pilsbry, 1907, p. 80, pl. viii, figs. 2, 7; Jennings, 1915, p. 287.

Specific Diagnosis.—" Valves smooth: scuta destitute of internal umbonal teeth; carina standing a little separate from the other valves, with the fork not close to the basal margin of the scuta; uppermost part of the peduncle either pale or orange coloured. Filaments three on each side." (Darwin.)

Locality.—Hull of " Terra Nova," Lyttelton Harbour (C. Chilton).

Lepas pectinata Spengler.

Lepas pectinata Spengler, 1793, *Skrifter Naturhist. Selbskabet*, 2 B., 2 H., Tab. x, fig. 2; Darwin, 1851, p. 85, pl. i, figs. 3, 3*a*; Hutton, 1878, p. 329; Gruvel, 1905, p. 107, fig. 119; Pilsbry, 1907, p. 81, pl. viii, figs. 4–8; Chilton, 1911A, p. 571; Jennings, 1915, p. 286; Borradaile, 1916, p. 131.

Specific Diagnosis.—" Valves thin, coarsely furrowed, often pectinated. Scuta with a prominent ridge extending, from the umbo to the apex, close to the occludent margin; fork of the carina with the prongs diverging at an angle of from 135° to 180°. Filaments absent, or only one on each side." (Darwin.)

Var. (*a*). " Upper part of the terga (bounded by the two occludent margins) produced and sharp; surface of all the valves often coarsely pectinated, and with the carina barbed." (Darwin.)

* This variety has been described as a new species by Borradaile, under the name *L. affinis* (see Borradaile, 1916, p. 131, and 1917, p. 229).—C. C.

Localities.—General type: Chatham Islands (A. Dendy).

Var. (*a*): Kermadec Islands (W. R. B. Oliver); Waitakerei River, washed up on beach (W. R. B. Oliver); off Three Kings Islands (L. A Borradaile).

Lepas australis Darwin.

Lepas australis Darwin, 1851, p. 89, pl. i, fig. 5; Hutton, 1879, p. 329; Gruvel, 1905, p. 109, fig. 122; L. S. Jennings, 1915, p. 285.

Specific Diagnosis.—"Valves smooth, thin, brittle; scuta with internal umbonal teeth on both sides. Carina with upper part broad, flat; much constricted above the fork, which has wide, flat, thin, pointed prongs, with the intermediate rim not reflexed. Filaments two on each side." (Darwin.)

Localities.—New Plymouth beach (Mrs. B. D. Jennings); Sumner (A. F. Barrell); New Brighton (G. E. Archey and L. S. Jennings); hull of "Terra Nova," Lyttelton Harbour (C. Chilton): Cape Campbell (T. McAlpine).

Lepas fascicularis Ellis and Solander.

Lepas fascicularis Ellis and Solander, 1786, Zoophytes, Tab. xv, fig. 5; Darwin, 1851, p. 92, pl. i, fig. 6; Hutton, 1879, p. 329; Gruvel, 1905, p. 105, fig. 116; Pilsbry, 1907, p. 81, pl. ix, fig. 6; Chilton, 1911A, p. 572; Jennings, 1915, p. 286.

Specific Diagnosis.—"Valves smooth, thin, transparent; carina rectangularly bent, with the lower part expanded into a flat oblong disc. Filaments, five on each side: segments of the three posterior cirri with triangular brushes of spines." (Darwin.)

Localities.—New Brighton (A. Dendy); Sunday Island, Kermadecs (W. R. B. Oliver); Waitakerei River, washed up on beach (W. R. B. Oliver).

Lepas denticulata Gruvel, 1900.

Lepas denticulata Gruvel, 1905, p. 106, fig. 118; Chilton, 1911A, p. 571; Jennings, 1915, p. 286.

Specific Diagnosis.—"Capitulum avec cinq plaques tres serrées, de couleur très blanche et fortement pectinées. Carène terminée en fourche à sa partie inférieure, chacune des branches portant, du côté pédonculaire, deux pointes saillantes, l'interne plus longue que l'externe; crête médiane dorsale avex quatre fortes dents et une série de plus petites entre les premières. Bord occluseur des scuta, convexe et fortement saillant antérieurement. Une dent à l'angle umbonal interne du scutum gauche. Rien à droite. Pas d'appendices filamenteux." (Gruvel.)

Locality.—Kermadecs (Captain Bollons, 1907).

Conchoderma auritum (Linnaeus).

Lepas aurita Linnaeus, 1767, *Systema Naturae*, ed. 12, p. 1110. *Conchoderma aurita* Darwin, 1851, p. 141, pl. iii, fig. 4; Chilton, 1911c, p. 132; Jennings, 1915, p. 287. *Conchoderma auritum*, Gruvel, 1905, p. 144, fig. 167; Pilsbry, 1907, p. 99, pl. ix, fig. 2; Pilsbry, 1909, p. 71, pl. viii, figs. 5, 6, 7; Borradaile, 1916, p. 132, and 1917, p. 230.

Specific Diagnosis.—" Capitulum with two tubular ear-like appendages, seated behind the rudimentary and often absent terga; scuta bilobed; carina absent, or quite rudimentary; peduncle long, distinctly separated from the capitulum." (Darwin.)

Localities.—Hull of " Terra Nova," Lyttelton (C. Chilton); from *Megaptera nodosa* in the Bay of Islands and off Cape Brett (L. A. Borradaile); on whales (specimens in Otago and Auckland Museums).

Conchoderma virgatum (Spengler).

Lepas virgata Spengler, 1790, *Skrifter Naturhist. Selbskabet,* B. 1, Tab. vi, fig. 9. *Conchoderma virgata* Darwin, 1851, p. 146, pl. iii, fig. 2: pl. ix, fig. 4: Chilton, 1911c, p. 132: Jennings, 1915, p. 287. *Conchoderma virgatum* Gruvel, 1905, p. 144, fig. 168; Pilsbry, 1907, p. 99, pl. ix, fig. 1; Borradaile, 1917, p. 230.

Specific Diagnosis.—" Scuta three-lobed: terga concave internally, with their apices slightly curved inwards: carina moderately developed, slightly curved: peduncle blending into the capitulum." (Darwin.)

Localities.—Hull of " Terra Nova," Lyttelton Harbour (C. Chilton); ship's hull, Dunedin (specimens in Otago Museum).

Scalpellum villosum (Leach).

Scalpellum villosum Leach, 1824, *Encyclop. Brit. Suppl.,* vol. iii, pl. lvii; Darwin, 1851, p. 274, pl. vi, fig. 8; Hutton, 1879, p. 329; Gruvel, 1905, p. 33, fig. 32; Pilsbry, 1907, p. 9; Jennings, 1915, p. 286.

Specific Diagnosis.—" Capitulum with fourteen valves: sub-rostrum present: carina nearly straight: three pair of latera; upper latera triangular. Mandibles with four teeth, of which the second is the smallest: maxillae with a projection near the inferior angle: no caudal appendage.

" Complemental male attached externally between the scuta, below the adductor muscle; pedunculated; capitulum formed of six valves, with the carina not descending much below the basal angles of the terga: mouth and cirri prehensile." (Darwin.)

Localities.—Stewart Island (W. R. B. Oliver); Port Robinson (J. R. Wilkinson); Godley Head (W. R. B. Oliver); Cheltenham Beach, Auckland (W. R. B. Oliver); Oamaru (L. S. Jennings).

Scalpellum spinosum Annandale.

Scalpellum spinosum Annandale, 1911, p. 164, figs. 1–4; Chilton, 1911B, p. 311; Jennings, 1915, p. 286.

Specific Diagnosis.—Capitulum broad, fifteen smooth pinkish valves present, covered with a minutely hairy translucent brownish membrane. Terga large, lozenge-shaped; scuta broadly triangular. Carina short, nearly straight, ridged dorsally but not laterally. Upper latera narrowly triangular. Rostrum, latera of the basal whorl, and subcarina prominent, pointed, spine-like. (Abridged from Annandale.)

Localities.—Farewell Spit, Nelson (W. B. Benham); " Nora Niven " Expedition, Station 5, off Stewart Island.

Pollicipes* spinosus (Quoy and Gaimard).

Anatifa spinosa Quoy and Gaimard, *Voyage de l'Astrolabe*, pl. xciii, fig. 17. *Pollicipes spinosus* Darwin, 1851, p. 324, pl. vii, fig. 4; Hutton, 1879, p. 329; Gruvel, 1905, p. 20, fig. 24; Jennings, 1915, pp. 286, 291, figs. 3*a*, 3*b*. *Pollicipes sertus* Darwin, 1851, p. 327, pl. vii, fig. 5; Gruvel, 1905, p. 22, fig. 25; Jennings, 1915, pp. 286, 291. *Pollicipes darwini* Hutton, 1879, p. 329; Gruvel, 1905, p. 21; Jennings, 1915, pp. 286, 291.

Specific Diagnosis.—"Capitulum with one or more whorls of valves under the rostrum: upper pair of latera only slightly larger than lower latera: membrane covering the valves (when dried) light yellowish-brown: scales of the peduncle of unequal sizes, unsymmetrical, arranged in rather distant whorls." (Darwin.)

Localities.—Kaikoura (collector unknown); Port Pegasus, Stewart Island (collector unknown); Russell, Bay of Islands (W. R. B. Oliver); Tauranga (W. R. B. Oliver); Godley Heads (W. R. B. Oliver); Stewart Island (W. Traill); Kaikoura (L. S. Jennings); Oamaru (L. S. Jennings); St. Clair, Dunedin (L. S. Jennings); Taylor's Mistake, Banks Peninsula (L. S. Jennings).

The reasons for considering *P. sertus* Darwin and *P. darwini* Hutton to be synonyms of *P. spinosus* Quoy and Gaimard have already been fully discussed. (See *Trans. N.Z. Inst.*, vol. 47, p. 291, 1915.)

Family BALANIDAE.

Balanus tintinnabulum (Linnaeus).

Lepas tintinnabulum Linnaeus, 1758, *Systema Naturae*, ed. 10, p. 668. *Balanus tintinnabulum* Darwin, 1854, p. 194, pl. i, figs. *a–l*; pl. ii, figs. 1*a*–1*o*: Gruvel, 1905, p. 211, figs. 230–33: Pilsbry, 1916, p. 54.

Specific Diagnosis.—"Shell varying from pink to blackish-purple, often striped and ribbed longitudinally: orifice generally entire, sometimes toothed. Scutum with the articular ridge broad and reflexed. Tergum with the basal margin generally forming a straight line on opposite sides of the spur."

"Var. (8) *concinnus*: Globulo-conical; walls finely ribbed: dull purple, tinged and freckled with white; scutum, with a broad, hooked, articular ridge, with an extremely sharp plate-like adductor ridge, and with a cavity, bordered by a plate, for the rostral depressor muscle." (Darwin.)

Locality.—Hull of "Terra Nova," Lyttelton Harbour (C. Chilton).

Balanus decorus Darwin.

Balanus decorus Darwin, 1854, p. 212, pl. 2, figs. 6*a*, 6*b*; Gruvel, 1905, p. 214; Chilton, 1909, p. 670, and 1911, p. 311, pl. 58, figs. 1–3; Pilsbry, 1916, pp. 53, 77.

Specific Diagnosis.—"Parietes pale pink; radii rather darker. Scutum with a small articular ridge. Tergum with longitudinal furrow very shallow and open; basal margin on both sides sloping towards the spur." (Darwin.)

Localities.—British Museum, from New Zealand (type); New Brighton

* In accordance with the rules of priority, Pilsbry uses the generic name *Mitella* in place of *Pollicipes* (see Pilsbry, 1907, p. 4, and 1911, p. 33).—C. C.

Beach (L. S. Jennings); Wanganui (S. H. Drew); Chatham Islands (Dr. E. Kershner); Auckland Islands (C. Chilton).

By the "Nora Niven" Trawling Expedition this species was taken at several localities on the New Zealand coast, many of them growing on the carapace of *Paramithrax longicornis* Thomson, with which crab the cirripede seems to be specially associated.

Balanus trigonus Darwin.

Balanus trigonus Darwin, 1854, p. 223, pl. 3, figs. 7*a*–7*f* Hutton, 1879, p. 330; Gruvel, 1905, p. 223, figs. 248, 249; Pilsbry, 1916, p. 111, pl. 26, figs. 1–13*e*.

Specific Diagnosis.—"Parietes ribbed, mottled purplish-red; orifice broad, trigonal, hardly toothed. Scutum thick, with from one to six longitudinal rows of little pits. Tergum without a longitudinal furrow; spur truncated, fully one-third of width of valve." (Darwin.)

Locality.—Rangitoto Reef, Auckland Harbour (W. R. B. Oliver).

Balanus porcatus Da Costa.*

Balanus porcatus Da Costa, 1778, *Hist. Nat. Test. Brit.*, p. 249; Darwin, 1854, p. 256, pl. 6, figs. 4*a*–4*e*; Filhol, 1885, p. 487; Gruvel, 1905, p. 237, fig. 264. *Balanus balanus* Pilsbry, 1916, p. 149.

Specific Diagnosis.—"Shell white, generally sharply ribbed longitudinally: radii with their summits almost parallel to the basis. Scutum longitudinally striated: tergum with the apex produced and purple." (Darwin.)

Localities.—Auckland (H. Suter); New Zealand (locality not stated) (W. R. B. Oliver).

Balanus crenatus Bruguière.

Belanus crenatus Bruguière, 1789, *Encyclop. méthod.* (des Vers), p. 168; Darwin, 1854, p. 261, pl. vi, figs. 6*a*–6*g*; Gruvel, 1905, p. 240, figs. 268, 269; Pilsbry, 1916, p. 165, pls. 39, 40.

Specific Diagnosis.—"Shell white: radii with their oblique summits rough and straight. Scutum without an adductor ridge: tergum with spur rounded." (Darwin.)

Localities.—Hull of "Terra Nova," Lyttelton Harbour (C. Chilton).

Pilsbry (1916) distinguishes several varieties of this species.

Tetraclita purpurascens (Wood).

Lepas purpurascens Wood, 1815, *General Conchology*, p. 55, pl. 9, fig. 42. *Tetraclita purpurascens* Darwin, 1854, p. 337, pl. xi, figs. 1*a*–1*d*; Hutton, 1879, p. 328; Gruvel, 1905, p. 285, fig. 308*a*; Pilsbry, 1916, p. 249.

Specific Diagnosis.—"Shell depressed, pale purple or dirty-white, with the surface longitudinally ribbed, or corroded and granulated: radii or even sutures none, or radii well developed and broad, with summits parallel to

* According to the rules of priority, this species should be named *Balanus balanus* (Linnaeus), the name adopted by Pilsbry in 1916. For convenience of reference to papers dealing with New Zealand Cirripedia the name used by Jennings in his manuscript notes has been allowed to stand in the text.—C. C.

the basis: basis membranous: scutum transversely elongated: tergum small, with the spur extremely short and rounded." (Darwin.)

Locality.—Otago (W. R. B. Oliver).

Elminius modestus Darwin.

Elminius modestus Darwin, 1854, p. 350, pl. 12, figs. 1*a*–1*e*; Hutton, 1879, p. 328; Gruvel, 1905, p. 296, figs. 319–322; Pilsbry, 1916, p. 261. *Elminius sinuatus* Hutton, 1879, p. 328; Gruvel, 1905, p. 295.

Specific Diagnosis.—"Shell folded longitudinally, greenish or white: radii of moderate breadth, smooth-edged: scutum without adductor ridge: tergum narrow, with the spur confluent with basi-scutal angle." (Darwin.)

Localities.—Lyttelton Harbour (L. S. Jennings); Riwaka, Nelson Harbour (L. S. Jennings); Takapuna Beach; Half-moon Bay, Stewart Island (W. R. B. Oliver); Ponui Island, Hauraki Gulf (C. Chilton).

E. sinuatus Hutton is probably only a variety of *E. modestus* Darwin. In groups of *E. modestus* many young specimens have parieties of each valve with two rounded folds, referred to by Hutton in his description of *E. sinuatus*. The two distinct folds show also when specimens are not crowded together.

Elminius plicatus Gray.

Elminius plicatus Gray, 1843, Appendix to Dieffenbach's *Travels in New Zealand*, p. 269; Darwin, 1854, p. 351, pl. 12, figs. 2*a*–2*f*; Hutton, 1879, p. 328; Gruvel, 1905, p. 296, figs. 318, 321; Pilsbry, 1907, p. 261.

Specific Diagnosis.—"Shell deeply folded longitudinally, corroded, coloured in parts orange: radii very narrow, with their edges sinuous, and slightly dentated: scutum having an adductor ridge." (Darwin.)

The valves show many variations in elongation of terga, prominence of grooves and ridges, straightness of tergal articular ridge, length and inflexion of tergal furrow, bluntness or beaked nature of apex.

The general appearance of the shell is also extremely variable. When very corroded the walls are extremely thick, by the inward production of the internal ridges, giving an appearance of porosity. These specimens are usually depressed, and are of a grey or dirty-white colour.

Localities.—Kaipara Harbour (Spencer); Shag Point, Otago (W. R. B. Oliver); Lyttelton Harbour (L. S. Jennings); Puhoi Beacon, Auckland Harbour (C. Chilton); Hawera (L. S. Jennings); Ponui Island, Hauraki Gulf (C. Chilton); Oamaru (L. S. Jennings); Takapuna, Auckland (W. R. B. Oliver).

Coronula diadema (Linnaeus).

Lepas diadema Linnaeus, 1767, *Systema Naturae*, ed. 12, p. 1109. *Coronula diadema* Darwin, 1854, p. 417, pl. xv, figs. 3, 3*a*, 3*b*; pl. xvi, figs. 1, 2, 7: Hutton, 1879, p. 329: Gruvel, 1905, p. 273: Pilsbry, 1916, p. 273, pl. 65, figs. 3, 4.

Specific Diagnosis.—"Shell crown-shaped, with longitudinal convex ribs, having their edges crenated; orifice hexagonal: radii moderately thick, very broad: terga absent or rudimentary." (Darwin.)

Localities.—Waikouaiti, on a whale (F. W. Hutton); on whale (specimens in Auckland Museum).

Chamaesipho columna (Spengler).

Lepas columna Spengler, 1790, *Skrifter Naturhist. Selbskabet*, B. 1, Tab. vi, fig. 6. *Chamaesipho columna* Darwin, 1854, p. 470, pl. 19, figs. 3*a*–3*c*; Hutton, 1879, p. 329; Gruvel, 1905, p. 282, figs. 306, 307.

Specific Diagnosis.—" Sutures, excepting during early youth, generally obliterated both externally and internally: tergum with small pits for attachment of depressor muscle." (Darwin.)

Localities.—Cuvier Island (Grenfell and Barr); Nelson (L. S. Jennings); Shag Point, Otago (W. R. B. Oliver).

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—— 1911. On the Nomenclature of Cirripedia, *Zool. Anz.*, Bd. 37, pp. 33–35.

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CORRIGENDUM.

Page 40, lines 7–8: *For* hypobasal *read* upper.

Art. IV.—*A New Species of Hypolepis.*

By H. Carse.

[*Read before the Auckland Institute, 11th December, 1917; received by Editors, 24th December, 1917; issued separately, 24th May, 1918.*]

Hypolepsis Petrieana sp. nov. Carse.

Hypolepis bipinnata, *H. millefolio* Hook. affinis: differt stipite glabro ± tuberculato; ramis primariis numerosis parum distantibus. Superioribus a rhachi angulis valde obtusis provenientibus; pinnis secundariis in lobos breves late obcuneatos, acutos, subacutos, v. fere obtusos, integros v. ± alte (plerumque a margine superiore) incisos, pro parte maxima alternos, sectis.

Sori parvi rotundati pauci, in lobis singulis, 1, rarius 2.

Rhizoma tenue, repens, squamis linearibus ferrugineis dense vestitum.

This undoubtedly new species of *Hypolepis* was discovered in December, 1907, by Mr. D. Petrie, M.A., Ph.D., with whose name I have pleasure in associating it.

Rhizome slender, creeping, thickly covered with linear rusty scales.

Stipes 4–6 in. long, rigid, moderately stout, erect, yellow (as are the rhachis and primary costae) or the lower part brownish, glabrous, somewhat rough with scattered depressed tubercles.

Fronds 12–14 in. long, 8–10 in. broad, broadly obcuneate-ovate, subrigid, bipinnate, secondary pinnae pinnatifid or their lower part pinnatisect; primary branches numerous, rather closely placed, the upper diverging almost at right angles.

Rhachis and primary costae sparingly or somewhat closely clothed with delicate crisped hairs; lower primary pinnae narrow ovate-lanceolate, 6–8 in. long, suberect or ascending, shortly stipitate, the upper gradually shorter, narrower, and more strongly diverging; secondary pinnae very shortly stipitate, broadly linear, 2¼ in. long or less, cut half-way down, or almost to the costa, into short entire or ± deeply cut (mostly at the upper edge) broadly obcuneate, acute, subacute, or almost obtuse, usually alternate, lobes, that are glabrous above and nearly so below; midrib with a few short hairs, chiefly on the under-surface.

Sori 1, or rarely 2, on each ultimate lobe, small, rounded, the common one partially covered by a very short reflexed lobule projecting from the upper basal border of the lobe, the second (when present) placed about half-way up the lower side of the lobe and more or less covered by its slightly expanded and recurved margin.

Indusium composed of the almost unaltered reflexed portions of the lobes described above.

Hab.—Vicinity of Otorohanga, Waipa County, and Port Charles, Coromandel County. D. Petrie!

ART. V.—*The Stratigraphical Relationship of the Weka Pass Stone and the Amuri Limestone.**

By R. SPEIGHT, M.Sc., F.G.S., Curator, Canterbury Museum, and Lecturer on Geology, Canterbury College; and L. J. WILD, M.A., B.Sc., F.G.S., Lecturer on Chemistry, Canterbury Agricultural College, Lincoln.

[*Read before the Philosophical Institute of Canterbury, 5th September, 1917; received by Editors, 31st December, 1917; issued separately, 24th May, 1918.*]

Plates IV–VII.

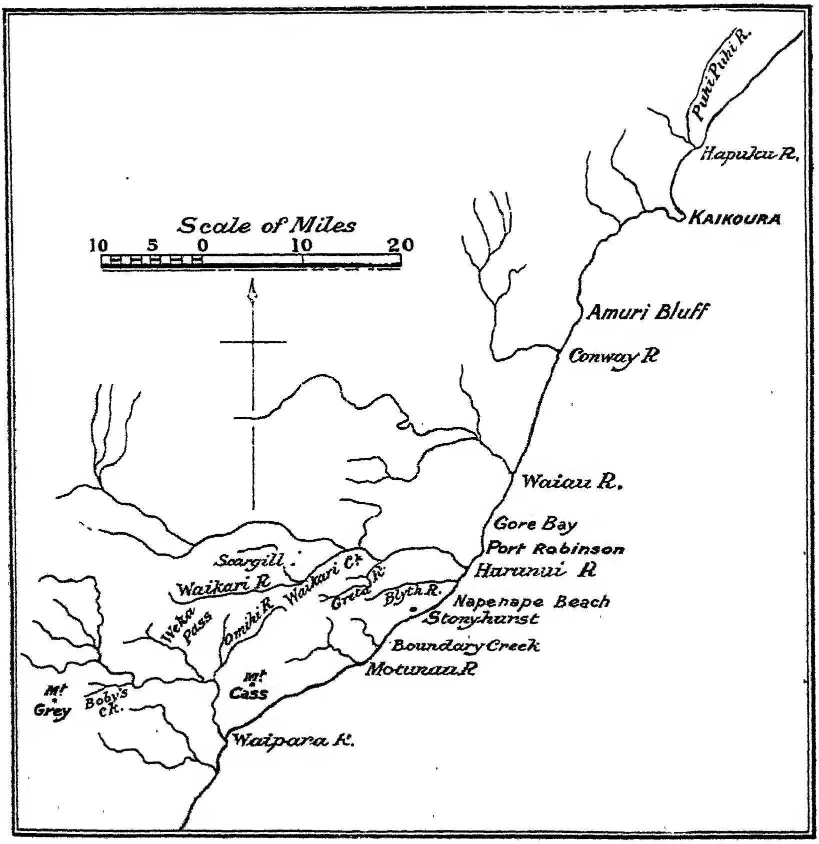
CONTENTS.

INTRODUCTION.

THE area referred to in this paper stretches from the neighbourhood of the Waipara River in a north-easterly direction across the Hurunui River, up the coast past Amuri Bluff, to just north of Kaikoura, a total distance of

* We desire to state that we have been enabled to make the observations recorded in this paper largely through the award of a grant by the New Zealand Institute for research work on the phosphate-bearing rocks of Canterbury.

about eighty miles (see map). Throughout the region there is a great development of the Tertiary sedimentaries, and some of the localities have been looked on as classical in the discussion of various points relating to New Zealand stratigraphy. Notably is this true of the areas in proximity to the Waipara River, the Weka Pass, and Amuri Bluff, probably no parts of New Zealand furnishing better opportunities for studying the relationship of beds with a Cretaceous fauna to those with a Tertiary fauna. Nevertheless there have been and now exist remarkable discrepancies of opinion on the part of writers, and as we have had in the course of our search for



Locality-map of part of the east coast of the South Island of New Zealand.

phosphatic rock ample opportunities to study the relationship of the beds in different localities, and, as many miles of outcrops have been carefully examined, especially those concerning which the discussion has been keenest, we consider it appropriate to place on record the result of those observations, as far as they affect the question of the stratigraphy, in the hope that they may aid in a definite opinion as to the points at issue being arrived at.

The most important question suggested by the investigation is the matter of the conformity or unconformity of two limestones which are

typically developed in the southern part of the area. The beds involved in this discussion are as follows, commencing from the bottom of the series :—

(1.) *Greensand.*

(2.) The *Amuri limestone*, an argillaceous limestone, named from its great development in the neighbourhood of Amuri Bluff, but also occurring, outside the area under consideration, in the valleys of the Clarence and Awatere, and perhaps in the south of the North Island.

(3.) A *nodular band*, less than 1 ft. thick, composed of phosphatic material of two kinds in a matrix of greensand or marl.

(4.) The *Weka Pass stone*, a glauconitic arenaceous limestone as it occurs in the typical locality at Weka Pass, but probably equivalent to the higher parts of the Amuri limestone elsewhere, and perhaps to the lower part of the next succeeding higher bed in localities near Kaikoura and Amuri Bluff.

(5.) The *Grey marl*, in its lower portions a glauconitic, arenaceous marl, which in its higher parts in some localities becomes distinctly argillaceous and takes on a true marly facies, and at times becomes decidedly sandy as it passes up into the next higher member of the series.

There follows a more detailed description of the second, third, and fourth of these beds, which are the most important as far as this discussion is concerned.

DETAILED DESCRIPTION OF THE LIMESTONES.

Amuri Limestone.

Although the macroscopic properties of the Amuri limestone have been fully described previously by various observers and its microscopic characters have been dealt with by Marshall (1916, p. 95), it may be as well to restate its salient features in this connection.

As typically developed south of Kaikoura it is an argillaceous limestone, breaking up freely into quadrangular blocks owing to the presence of a well-defined system of cross-joints, a property which is eminently characteristic of it wherever it occurs. Owing to some of these blocks being thin and flaky, its surface takes on a tile-like appearance, especially where inclined beds are exposed on a shore-platform. This character is shown throughout the whole thickness of the limestone at Kaikoura and at Amuri Bluff, but farther south, as at Weka Pass, the so-called Weka Pass stone (the higher part of the Amuri limestone as maintained by the authors) does not exhibit to a marked degree this jointed structure, though echoes of it are undoubtedly present.

The rock is at times chalky in texture, but is usually hard and occasionally crystalline, especially where it has been subjected to pressures resulting from earth-movements. Notably is this the case at Kaikoura, where it sometimes takes on a subschistose character. Mention should be made here of the chalk deposit at Oxford, which represents this rock in the Waimakariri basin, judging from stratigraphical and lithological evidence.

The microscope shows the presence of numerous grains of glauconite even in the white-coloured rock, but distinct layers and lenticules of greensand occur at times, as can be seen in localities like Weka Pass, though it occurs more freely farther north. At Kaikoura it occurs right through the stone, but more especially at the higher levels, where it is organized into

well-defined layers, this being especially the case above the zone of phosphatic nodules. Similar well-defined interstratified greensand bands are noted by McKay and by Thomson as occurring in the development of Amuri limestone in the valley of the Clarence. This is important, seeing that this higher portion, notably at Kaikoura, has been definitely recognized by various authorities as belonging to the Amuri limestone and not separated from it by any unconformity.

Another notable constituent of the limestone is flint, which occurs in lenticules and in irregular masses, as has been fully described by Thomson (1916, pp. 52–58). In Marlborough flint is specially important, but the amount progressively diminishes on being traced south. It is a well-marked constituent at Amuri Bluff and at Gore Bay, and it also occurs in the chalk deposits at Oxford, thus having a somewhat wider distribution than might be inferred from Thomson's paper. The flint is found both above and below the layer of nodules in the Kaikoura and Amuri Bluff districts, so that its presence or absence cannot be regarded as a criterion of age. Thomson has regarded the flint as formed by chemical precipitation (1916, p. 56). If that is so it must have been precipitated subsequently to the boring of the limestone, unless the boring animals have been able to penetrate flint itself, as the flint occurring *in situ* occasionally shows burrows filled with glauconitic material.

The lower portions of this limestone are decidedly more argillaceous, and merge into a true marl.

Table I.—Analyses of Amuri Limestone from Weka Pass.

	(1.)	(2.)	(3.)	(4.)	(5.)
SiO_2	11·12	7·52	6·74	7·25	14·45
Al_2O_3	1·78	1·64	1·50	0·66	1·03
Fe_2O_3	..	..	..	0·54	0·77
CaO	46·55	49·33	49·75	49·64	45·67
MgO	0·22	0·22	0·67	0·45	0·61
P_2O_5	0·28	0·19	0·12	n.d.	n.d.
CO_2	36·41	38·49	38·76	39·00	35·89
Moisture and organic matter..	1·74	1·05	1·20	2·06	1·58
Alkalis, &c.	1·90	1·56	1·26	0·40	..
	100·00	100·00	100·00	100·00	100·00

(1.) Amuri limestone at contact, near railway viaduct.
(2.) Amuri limestone, upper layer, same locality.
(3.) Amuri limestone, 35 ft. below upper surface.
(4.) Average sample, thickness of 40 ft.
(5.) Sample 2 ft. below upper surface.

Table II.—Partial Analyses of Amuri Limestone from Kaikoura.

	(1.)	(2.)
Insoluble in acid	11·96	10·40
Fe_2O_3 and Al_2O_3	3·20	4·80
$CaCO_3$	82·60	82·62
P_2O_5	0·57	0·51

(1.) Sample 2 ft. to 4ft. below contact.
(2.) Sample at the contact.

The Nodular Layer.

This layer is most important, as giving some idea of the conditions which obtained in the interval between the deposit of the two limestones, and therefore it will be described in detail. The most important constituent in point of volume is a calcareous greensand which fills borings in the upper surface of the Amuri limestone and passes up into the overlying Weka Pass stone, the lower parts of which are decidedly glauconitic, and there is apparently no pronounced line of division between them. Included in this matrix of greensand are numerous nodules which are more or less phosphatic, so that it may be called the phosphatic nodule bed. This nodular material is of two kinds—(1) true phosphatic nodules, and (2) nodular masses of Amuri limestone.

Phosphatic Nodules.—The descriptions of similar nodules occurring in deep water south of the Cape of Good Hope, on the Agulhas Bank, as given in the reports of the "Challenger" Expedition ("Deep-sea Deposits," p. 396) applies so exactly that we can use the same words to describe appropriately those occurring in our own limestones. The description is as follows: "The concretions vary from 1 to 3 cm. in greatest diameter; exceptionally they may attain from 4 to 6 cm. in diameter. They are surmounted by protuberances, penetrated by more or less profound perforations, and have on the whole a capricious form, being sometimes mamillated with rounded contours and at others angular. Their surface has generally a glazed appearance and is usually covered with a thin dirty brown coating, a discoloration due to the oxides of iron and manganese." The description further points out that grains of glauconite form a notable constituent in their composition, and especially is this the case in those from shallower water, which are larger and have a greenish-coloured external appearance. This is important, as the great majority of those found in the limestones have a greenish-coloured external appearance. The concretions are described as being hard and tenacious, "the fundamental mass, in spite of its earthy aspect, being compact, and having a hardness that does not exceed 5." This description so fits the nodules in the greensand layer that one cannot help suspecting a similarity of origin in the two cases.

For the purpose of comparison of the chemical composition we quote three analyses—the first, of one of the Agulhas Bank nodules; the second, one cited by McKay (1887, p. 84), of a nodule from the greensand layer at the Weka Pass; the third, of a nodule collected by us at Boundary Creek.

Table III.

	(1.)	(2.)	(3.)
SiO_2	14·78	..	17·25
Al_2O_3	3·34	..	..
Fe_2O_3	3·87	..	..
CaO	39·58	42·17	45·90
MgO	0·84	..	0·72
P_2O_5	19·96	17·45	21·12
CO_2	12·05	15·36	..
SO_2	1·37	..	..

It is unfortunate that the second and third analyses are not more complete, but the general similarity of the results obtained will be noted.

The nodules from deeper water, as pointed out subsequently in the report (p. 393), differ from those just referred to, and the same applies

to those reported on by Murray as occurring in the "Bottom deposits" obtained by the "Blake."*

The association of nodules with greensand does not, however, point to a genetic connection between the two, since nodules are found on the bottom of the present sea not associated therewith. They are of different origin and character, as may be inferred from the report on the "Blake" deposits, and as is noted in the report of the "Challenger." The point is well brought out by Collet and Lee† :—

"La glauconie et ses concrétions phosphatées se forment actuellement sur le fond des mers, existe-t-il une relation entre ces deux formations au point de vue de leur genèse ? Cette question se pose naturellement quand on étudie les dépôts marins, et nous croyons être maintenant en mesure d'y répondre négativement.

"Les concrétions phosphatées sont pour ainsi dire l'image du fond dans lequel on les rencontre, ce qui prouve bien leur formation in situ. Ce fond est-il sable vert, comme dans le cas de l'Agulhas Bank, les concrétions phosphatées contiendront de la glauconie en grand abondance ; est-il une boue à globigérines formée non loin du continent mais en eau profonde (3,475 mètres pour un des échantillons du Challenger), la concrétion sera entièrement formée de globigérines avec minéraux détritiques mais sans glauconie."

Therefore the association of the greensand with phosphate nodules in the case of the limestones merely indicates that the nodules were formed on a sea-bottom at such a depth that greensands were being laid down at the same time. The depth was approximately that at which the limestones also were being deposited, as is evidenced by the interstratification of the greensand and limestone and the presence of glauconite grains in the limestone. The Amuri limestone has been shown by Marshall (1916, p. 95) to be practically equivalent to an ooze, and its chemical composition shows that it contains over 80 per cent. of $CaCO_3$, so that it may be concluded, judging from the table given in the "Challenger" report (p. 79), that the depth was under 1,000 fathoms.

Microscopic Description of a Typical Nodule.—Under the microscope the base consists of irresolvable matter, probably calcite, with numerous tests of Foraminifera, and small fragments of quartz, feldspar, and occasionally mica. The base contains patches of microspherulitic structure, exhibiting between crossed nicols a well-marked cross with dark arms parallel to the cross-wires. They resemble to some extent small spherules of chalcedony, but from their high polarization colours they are no doubt composed of radiating fibres of calcite. There is a greenish stain of glauconite all through the slide, and the mineral at times forms distinct grains, in many cases filling the cavities of Foraminifera. These last are very numerous and constitute the bulk of the rock. The following genera were recognized: *Globigerina* (which is by far the most important), *Textularia*, *Nodosaria*, *Rotalia*. Radiolaria are also present. The glauconite is light-green as a rule, but occasionally dark-green and black aggregates also occur as a result of the peroxidation of the iron present. Small fragments of bone were also noted in one of the nodules.

Nodular Limestone.—This second class of phosphatic material consists of detached portions of the Amuri limestone included in the greensand.

* *Bull. Mus. Comp. Zool.*, vol. 12, p. 52, 1885–86.

† Recherches sur la glauconie, *Proc. Roy. Soc. Edin.*, vol. 26, pt. 4, p. 266, 1906.

which have an origin quite distinct from the true phosphatic nodules referred to previously. The nodular limestone, though easily recognized in the hand-specimen, differs little from the true nodules under the microscope, except that it is less glauconitic and approaches very closely to normal Amuri limestone. There can be no doubt that for a considerable period the limestone formed the ocean-floor (as is indicated by the phosphatic nodules), and that it was honeycombed by the borings and burrows of marine organisms operating at that depth, and that the additional phosphatic material was obtained from the ordinary limestone by a process of concentration, and from remains of those organisms responsible for the burrows. It is quite intelligible that during a period of halt in the deposition the solvent action of sea-water would cause a disappearance of a portion of the floor, and, as the phosphatic material is less soluble than the calcareous, some concentration of the phosphate would result.

This idea finds strong support in the following partial analyses of specimens obtained at Weka Pass. At this particular section the Amuri limestone is seen to be perforated to a depth of 4 ft. 6 in., the cavities being filled with the calcareous greensand that represents the overlying Weka Pass stone at this locality. The upper 18 in. of the Amuri limestone is much honeycombed with burrows, and completely detached fragments are to be found lying within the Weka Pass stone as much as 6 in. above the present surface of the Amuri limestone. It is to be understood that we look upon these nodular fragments as remnants of the original upper portion of the Amuri limestone which, during a halt in the deposition, was broken down by the combined action of boring-animals and solution by sea-water, some at least of the phosphate so set free being concentrated in the residual portions of limestone.

Table IV.

	(1.)	(2.)	(3.)	(4.)
Insoluble in acid	12·08	11·95	11·52	55·68
CaO	48·65	42·20	44·85	..
P_2O_5	0·16	0·45	4·09	1·34

(1.) Sample 2 ft. from present surface of Amuri limestone.
(2.) Sample from upper 6 in. of honeycombed portion of Amuri limestone.
(3.) Detached nodules of Amuri limestone lying in the Weka Pass stone a few inches above the present surface of the Amuri limestone.
(4.) Lower 2 ft. of Weka Pass stone.

In both types of nodules there is little difference from the associated limestone in the character of the Foraminifera and general structure of the rock, and they seem to have been formed under similar conditions. The description applies to specimens from Amuri Bluff and Stonyhurst equally with those from Weka Pass.

Under the microscope the material that fills the borings appears to be composed of much the same material as the associated limestone, and resembles in texture the Amuri limestone rather than the Weka Pass stone. There is, however, more granular glauconite, and there are more numerous shreds of mica and fragments of quartz. The glauconite does not fill the cavities in the Foraminifera so markedly, though undoubtedly some are filled. The genera of Foraminifera appear to be the same as in the Amuri limestone, *Globigerina*, *Nodosaria*, and *Rotalia* being clearly recognizable.

Weka Pass Stone.

In the typical locality near Weka Pass this rock consists of an arenaceous, glauconitic limestone. In its lower portion the rock presents the facies of a calcareous greensand of very fine grain, with a comparatively low percentage of calcium carbonate, but this percentage increases in the higher levels. (See analyses.) Specks of glauconite are, however, distributed throughout the rock. It breaks at times into quadrangular blocks, but rarely with the tily arrangement which characterizes Amuri limestone, though at times there is considerable similarity between the two rocks. Under the microscope it appears to be composed largely of Foraminifera, notably *Globigerina*, with a considerable amount of quartz and occasional shreds of biotite. The glauconite exists as grains, sometimes as a stain on the quartz, and occasionally filling the cavities of Foraminifera. As compared with Amuri limestone it is coarser in texture, more glauconitic and arenaceous; but the Foraminifera appear to be the same, and, as in the former case, have their cavities filled with calcareous material. The depth at which deposition took place would in all probability be slightly shallower than that at which the Amuri limestone was laid down.

Away from the typical locality the rock exhibits considerable variation. It is sometimes more glauconitic, and in fact passes into a calcareous greensand; while in other places it becomes more sandy and friable. The former of these two facies represents in all probability a deposit either in shallower water or nearer a shore-line, but there is no doubt as to its equivalence to the more calcareous rock. It is perhaps not truly synchronous, in that it may mean the gradual extension of the deposit into shallower water as physical conditions in the area changed; but the stratigraphical position and the relationship of the two facies to the underlying Amuri limestone are practically identical.

Table V.—Analyses of Weka Pass Stone.

	(1.)	(2.)
SiO_2	34·95	22·51
Al_2O3	6·44	3·92
Fe_2O_3	2·76	2·08
$CoCO_3$	47·62	67·60
$MgCO_3$	1·46	0·80
CaO	1·50	0·80
P_2O_5	n.d.	n.d.
Organic matter and water	3·50	2·29

(1.) Weka Pass stone 2 ft. above Amuri limestone. (Coll. J. Park.)
(2.) Weka Pass stone, average sample "from Waikari end of Weka Pass, from cliffs N.E. of stream a few chains above the railway viaduct." (Coll. J. Park.)

Historical Summary.

The following is a summary of the opinions held by the authors cited in the bibliography at the end of the paper, in the order of time in which they are expressed:—

Hector says (1869, p. xii), "The above (3 and 4) [grey marl] rest unconformably on blue and grey marly sandstone, sometimes passing into chalk, the formation resembling, in mineral character, the English chalk marl. In the same formation, farther north, flints occur." There is some doubt

concerning the proper interpretation of the beds as detailed by Hector, but the record of cup-shaped Bryozoa as occurring in (4) evidently points to what is called the grey marl in the Waipara section, and the beds with flints to the Amuri limestone, and the grey marly sandstone to the Weka Pass stone. It is evident, therefore, that Hector did not recognize an unconformity within the beds indicated above.

Haast evidently considered the two beds of limestone as quite conformable. He says (1879, p. 297), " In some localities a break seems to occur between the upper and lower calcareous series, as, for instance, in the Weka Pass ranges, where the lower, more calcareous strata are sometimes separated from the glauconitic massive upper beds by a small band of greensand containing concretions of a more calcareous nature. However, in many other localities this small bed does not occur, and the boundary between the two series is either gradual or sharpy defined. Moreover, the upper beds are found to be always conformable upon the lower where the latter exists, being, in fact, a continuation of the same series, and, owing to the sinking of the land, of greater horizontal extent than the more calcareous beds underlying them." We have quoted this description in full as it appears to us to explain concisely the whole case.

Hutton (1877, 1885, 1888) always maintained the unconformable relationship between the Amuri limestone and the Weka Pass stone, urging that the contact was a normal erosion-surface, and in none of his writings cited in the bibliography does he depart in the slightest from this position.

McKay (1881, 1886, 1887) considered the sequence conformable.

Thus it is that, among the older geologists of this country who have reported on this matter, three agree that the sequence is conformable, while one maintains the contrary.

We come now to the opinions of those of a more modern date. The first to be considered is that of Professor Park, who forms a kind of link with the older geologists. His views are by no means certain, and exhibit considerable evolutionary development. In his report published in 1888 he says, " As a result of the examination of many of the magnificent sections between the Weka Pass and the Waipara, I am strongly of the opinion that a complete sequence of beds exists from the base of the Cretaceo-Tertiary to the close of the Pareora formation, although the varying character of the deposits and their fossil remains show that the sea-bottom on which they were deposited was subject to frequent oscillation." Again (1905, p. 546), he says, " Captain Hutton contends that there is an unconformity between the Weka Pass stone and the Amuri limestone. I have carefully examined the line of contact of the two rocks, but was unable to find any evidence of unconformity; and on this point my view coincides with that of Sir James Hector, Sir Julius von Haast, and Mr. McKay." In his *Geology of New Zealand* (1910) Park evidently regards the two limestones as conformable, a position which he maintained in 1911 (p. 546). Next year, however, as a result of the finding of *Pecten huttoni* in the Weka Pass stone, he moved his unconformity to the base of the Weka Pass stone, which he then stated lay conformably under the Mount Brown limestone, although he had in 1888 demonstrated on stratigraphical grounds the existence of an unconformity between them. His position, therefore, seems somewhat obscure.

Marshall (1911, 1912) has always maintained the physical conformity between the beds of this series, and in this he has been supported by Cotton and Speight, both in conjunction with him (1911) and independently (1912).

Thomson also (1912, p. 8) has noted the physical conformity of the beds in the typical locality, whereas Morgan (1915, pp. 90–93), the latest writer on the subject, as a result of a hurried visit came to the conclusion that the top of the Amuri limestone presented a true erosion surface, but as the result of more complete examination of the relationship of the beds expresses himself in a less dogmatic manner (1916, pp. 17–28, and 1916A, pp. 10–11), and has evidently some doubts as to the correctness of his first interpretation, although he still agrees tentatively with Hutton and Park in his latest pronouncement.

Detailed Descriptions of Important Sections.

In order to arrive at a thorough appreciation of the problem a detailed description will be given of all localities where contacts occur from the neighbourhood of Mount Grey to just north of Kaikoura, and from the sea-coast as far inland as limestones occur which furnish any evidence. This ranges over a belt of country nearly one hundred miles in length and with a maximum breadth of fifteen miles. The localities first taken are those in the neighbourhood of Weka Pass, the typical locality; then those near the Waipara River and Mount Grey. They are followed north-east to Cheviot, when a return is made along the coast by way of the Hurunui mouth, Stonyhurst, and Motunau; and the series concludes with those at Amuri Bluff, Kaikoura, and the Puhipuhi River. We do not think that any important locality in that area has been omitted from consideration. It will be noticed that there is a general similarity of the sections throughout the area, both in its length and its breadth, which the advocates of unconformity will find difficult to explain, while the evidence for conformity is particularly strong.

Weka Pass.

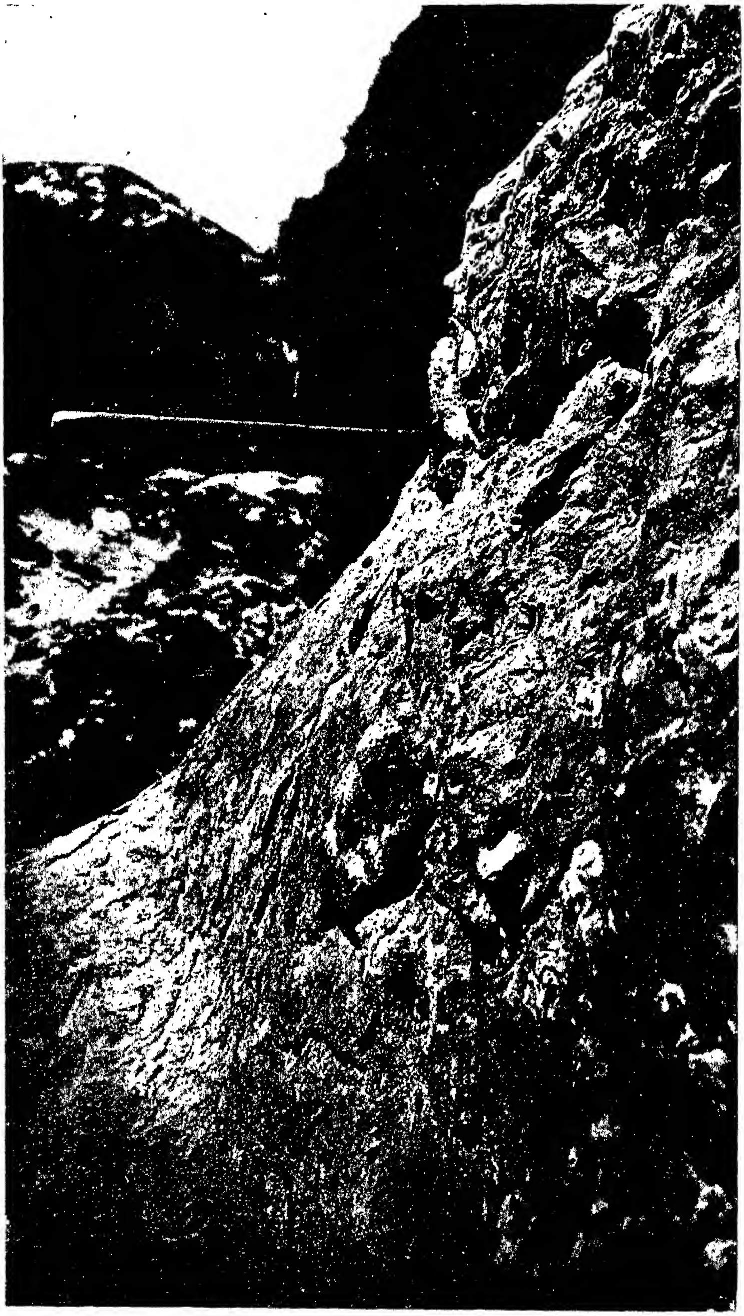
Good contacts can be seen at various places in the neighbourhood of the pass—*e.g.*, on the roadside just past Seal Rock, in the little gorge near the viaduct, on the northern face of the escarpment just east of the viaduct, and on both sides of the denuded anticline to the west of the viaduct. (Plates IV and V.) The following description fits in each case:—

(1.) *Amuri limestone:* White, and jointed into flaky quadrangular blocks, the upper 2 ft. or more being bored by marine worms and the casts filled with glauconitic limestone. The amount of boring increases progressively upward till what may be called the transitional layer is reached.

(2.) *Transitional layer:* This consists in its lower part of Amuri limestone material thoroughly bored, with the interstices filled with glauconitic limestone. The result of boring increases progressively, and the quantity of glauconitic material also increases *pari passu*. The upper 6 in. is completely bored, so that peninsulas of Amuri limestone project at times into the overlying glauconitic layer, and at times become detached and resemble subangular pebbles in appearance. They are more phosphatic than the underlying limestones, and the included glauconitic limestone is more phosphatic than the overlying glauconitic layer. The number of residual fragments of limestone decreases till they are entirely absent from the distinct layer of strongly glauconitic limestone. Included in this band are small angular nodules, green or black in colour, which are strongly phosphatic. Very occasionally, small well-rounded pebbles of quartz, about ¼ in. in diameter, are met with.

[R. Speight, photo.

Contact of Amuri limestone and Weka Pass stone, showing nodules of phosphatized Amuri limestone, on roadside, Weka Pass.



[R. Speight, photo

Contact of Amuri limestone with Weka Pass stone on escarpment east of viaduct, Weka Pass. Detached fragments of Amuri limestone can be seen in the Weka Pass stone.

(3.) *Glauconitic calcareous sandstone:* This is a distinct layer, about 6 in. thick, of strongly glauconitic fine-grained calcareous sandstone, which passes up into Weka Pass stone.

(4.) *Weka Pass stone:* This is a distinctly glauconitic, arenaceous limestone. The green and black nodules which mark the contact appear to diminish in number on going south-west along the escarpment, but they are occasionally present and so mark a continuous horizon; but on approaching the Waipara River the difference between typical Amuri limestone and Weka Pass stone disappears, and the contact becomes indefinite—in fact, the two beds merge into one limestone without any break.

Main Branch of Weka Creek.

There is an excellent exposure of the contact in the branch of the Weka Creek north-west of the main road, just where it is crossed by the subsidiary road running from Weka Pass behind the Mount Brown escarpment in the direction of the Waipara River. The stream has in this locality cut a deep narrow gorge right across the strike, and the contacts of the Weka Pass stone with the underlying Amuri limestone as well as with the overlying grey marl are excellently shown, both being quite conformable.

In the case of the former contact we have the following sequence:—

(1.) *Amuri limestone,* breaking into quadrangular blocks, with interstitial calcareous greensand in layers parallel to the bedding in its upper portions, very occasional burrows extending to 6 ft. below the actual junction. On approaching the junction the amount of greensand becomes greater, both in layers and in burrows, till near the contact the two form nearly equal proportions in the rock. Thereafter the Amuri limestone diminishes in importance, and inclusions of limestone in the greensand become rare. Dark-green and black nodules (phosphatic) as well as ironstone concretions also occur. The thickness of the layer where the two occur is about 12 in.

(2.) *Greensand layer,* without inclusions of Amuri limestone, about 1 ft. in thickness, but passing up into

(3.) *Weka Pass stone* in its typical development.

The contact between the two limestones is clearly seen on the escarpment to the north, and is visible at times on the south as far as a limestone knob a mile south of the creek, when for some distance towards the Waipara the junction is obscured. As far as it is visible it displays the same characteristic features.

Upper Waipara.

Excellent sections showing the relationship of the two facies of the limestone are to be seen above the limestone gorge of the Waipara River along the bold escarpment facing north-west. At the gorge itself there is the following sequence:—

(1.) The *marly facies* of the Amuri limestone forms the lowest portion in this locality, and passes up into

(2.) Typical jointed *Amuri limestone* with interstratified bands of argillaceous and glauconitic limestone. The upper layer of Amuri limestone is a compact white rock containing glauconite, the upper 6 ft. or 8 ft. with a concretionary fracture and passing up into

(3.) *Weka Pass stone* of more than usual glauconitic character.

No nodules or borings are present on the line of junction, which is indistinct one rock gradually passing into the other.

Along the escarpment to the south-west the same general features are to be observed, the Amuri limestone being decidedly glauconitic at times and the greensand layer at the junction more marked than near the gorge, while the Weka Pass stone exhibits in places the typical facies, though in others it is like the Amuri limestone, and in others again it is of sandy texture, approaching a freestone, and is so friable that it can be rubbed into powder with the fingers.

At the point where shells of *Pecten huttoni* are found in the Weka Pass stone, which is a few chains east of the low part of the escarpment where the road crosses, the junction presents the usual features of worm-borings and the presence of scattered dark phosphatic nodules, while on the weathered surface of the Amuri limestone there are small protuberances of limestone, evidently more resistant than the remainder of the rock, and owing their preservation to the presence in them of an amount of calcium phosphate in excess of that in the surrounding rock.

When traced west the limestone outcrop passes over into the watershed of Boby's Creek, and in the bed of its most northerly tributary an excellent exposure is to be seen. This is as follows :—

(1.) *Amuri limestone*, the upper 3 ft. bored more and more till the junction is reached, the borings being filled with greensand. Detached fragments of more phosphatized limestone occur along the junction. The limestone is here much thinner than it is on the escarpment to the north-east, and thins out still more when followed to the south-west towards Mount Grey.

(2.) *Nodular layer:* This consists mostly of detached fragments of limestone, the true nodules being small; all are enclosed in a greensand matrix. A well-rounded pebble of greywacke was found embedded near the junction, indicating in all probability the close proximity of a shore-line. This passes up into

(3.) *Greensand*, with fewer and fewer nodules.

(4.) *Weka Pass stone*, more glauconitic than usual, as is usually found as the deposits approach an outstanding greywacke mass; in this case it is that of Mount Grey. In the lower part of this layer shells of *Pecten huttoni* were found in a somewhat poor state of preservation.

The strike of all the beds is north-east and south-west, with a dip to the south-east of 35°.

No evidence of unconformity, excepting the pebble, is given by this locality, although it affords ample opportunity for locating one did it exist. The interstratification of glauconitic limestone in the Amuri stone indicates that no great change in depth occurred between the deposit of the typical Amuri limestone and the Weka Pass stone, the interstratification of the glauconitic material in the former preparing the way for the final development of the pronounced glauconitic type.

North-east Slope of Mount Grey.

The fine escarpment which runs south-west through Mount Brown towards Mount Grey is deflected when it reaches the vicinity of the mass of greywacke of which the latter is composed, no doubt partially owing to earth-movements, of which there is decided evidence in the locality.

A well-defined fault-scarp runs along the eastern face of the mountain in a north-west and south-east direction in a line with the western margin of the depression which continues towards Heathstock and the Upper Waipara basin. On the western side of this, in the vicinity of Mount Mason and elsewhere, there is evidence of deformation where the limestones abut against the older rocks. This line of deformation evidently belongs to the series of north-west and south-east earth-fractures which are characteristic of the mountain region of Canterbury. As a result of this and related movements the Mount Brown beds and the underlying limestones are bent round till on the divide between Boby's Creek and Kowai River they strike north-west and dip to the north-east at high angles, about 70°. The edges of the beds are thus exposed, and the relations of the Amuri limestone to the beds immediately overlying it are well seen in one or two places. The sequence is here as follows:—

(1.) *Amuri limestone,* of the usual type, well jointed, and not more than 25 ft. thick; it thus shows the characteristic thinning-out as it approaches a shore-line. In its upper layers it is glauconitic, and deeply bored, with the borings filled with greensand.

(2.) *Nodular layer:* This is about 4 ft. wide, with pieces of limestone in a matrix of greensand. This bed is closed with a fairly well-defined layer of fragments in which limestone predominates over greensand, as if there were a partial reversion to limestone conditions when this part of the bed was being deposited. The calcareous nodules are distinctly bored, and show a marked qualitative reaction for phosphoric acid. There are occasional small, rounded, dark-greenish nodules, up to ¾ in. in diameter, but these are more important in the next bed.

(3.) *Calcareous greensand,* strongly glauconitic. It appears that the Weka Pass stone takes on this decidedly glauconitic facies as it approaches a shore-line, and also the phosphatic nodules are apparently more numerous under these conditions, suggesting a resemblance to the conditions obtaining on sea-bottoms of the present day where greensands and green muds are associated with these nodules.

South Branch of Omihi Creek.

South-east of the Omihi Valley, and dividing its drainage area from that of the slopes facing seaward, lies the prominent limestone escarpment of the Cass, or Limestone, Range as it is sometimes called. On its northern side there are excellent exposures of the limestones and the underlying sands and sandstones resting unconformably on the Trias-Jura beds. Owing to a fault which runs approximately north-east and south-west, with a throw of some 1,000 ft. to the north-west, the outcrops are repeated, and we thus get two sections which show the horizon of the nodular layer. They exhibit a striking difference, however. One section has a facies which shows the proximity of a shore-line, in agreement with the fact that the Trias-Jura beds are in evidence but a few hundred yards away in the direction of the rise of the beds, whereas the other section, about a mile and a quarter to the south-east, has a facies which is characteristic of deeper water.

The first of these sections is well displayed near a small waterfall on the east side of the road which runs south past the shepherd's hut in the direction of the limestone escarpment. The typical Amuri limestone is here

absent, but it is represented stratigraphically by a strongly glauconitic limestone, whose glauconitic character is strongly marked in the flaky quadrangular blocks into which the stone is divided, but more strongly still in the interstitial portions. A well-defined layer of nodules occurs in this limestone, the matrix being a markedly glauconitic limestone. The nodules are of two types—(1) ordinary phosphatized limestone, and (2) small dark-green nodules up to 1 in. in diameter, scattered through the nodular layer and through the next 4 ft. of the bed above. The nodular layer is not so well defined as usual, but passes gradually into the beds above and below it. Worm-borings are a feature of the occurrence, and there is an entire absence of any evidence of unconformity. The whole arrangement gives a good illustration of the modification in the character of the Amuri limestone as it approaches a shore-line, and supports the contention of some writers that greensand can be laid down in comparatively shallow water.

The other type of contact showing the relations of the Amuri limestone to the Weka Pass stone can be clearly seen on the northern slope of the escarpment to the south at an elevation of between 1,600 ft. and 1,700 ft. The following is a description of the contact as seen over a considerable length of the escarpment: The Amuri limestone is from 150 ft. to 200 ft. in thickness, well stratified and jointed, divided by narrow layers of more or less marly material in the lower part and by seams of glauconitic material in the higher part, with occasional worm-borings on the top of the hard limestone layers. These borings are filled with marly material in the lower parts and by glauconitic material in the higher parts, corresponding to the character of the layer which was being deposited while the borings were being made. Glauconitic material becomes more pronounced in the higher parts till it passes into the Weka Pass stone, which is here slightly more glauconitic than in the typical locality. The sequence is perfectly conformable throughout, the limestones changing from the Amuri to the Weka Pass facies with characteristic passage beds in which the two types are interstratified along the line of junction. In some places it is difficult to tell the precise line of demarcation of the two. No nodules were seen.

North Side of Waikari Creek between Waikari and Scargill.

On the north side of this stream lies a prominent band of limestone with a west-south-west strike, dipping south-south-east. It is a remnant of a more extensive covering sheet of Tertiary sedimentaries which has been faulted into a position less exposed to destructive agents as a result of earth-movements which have affected the whole region. The main fault-line follows approximately the line of the stream-valley, but a number of subsidiary faults running parallel to this on its northern side are plainly in evidence in the upper basin of the Scargill Creek, where there are a number of parallel belts of limestone, generally dipping south-east, the repetition of the outcrops being directly attributable to this series of faults. The steep scarps face north-west, and they give good opportunities for examining the limestone through its whole thickness. Specially good exposures occur on the north side of the high escarpment behind the greywacke barrier which divides the Scargill basin from the Waikari Valley, and fronting the stripped surface of greywacke which separates the former from the Culverden basin. The section shows that the limestone band is composed of alternating layers of more or less glauconitic material, some of which, usually the less glauconitic, have the jointing characteristic of the Amuri limestone, while

other layers have the Weka Pass stone facies. Worm-borings are found at various levels, and very occasional nodules are sporadically distributed.

Rock of similar features is to be seen on the north bank of the Waikari Creek about two miles below the Waikari Township. In this place fragments of whale-bone occur in rock of the Weka Pass type.

There is no evidence in either of these localities of any break in the succession, the whole being certainly conformable. Although there is some variation in the lithological character of the rock from that in typical localities, yet there is no reason to suppose that it has not been formerly in close lateral continuity with the masses on the south side of the valley which show the typical differentiation into stone of two facies. There is just the difference that one would anticipate were the beds north of the Waikari deposited in an area in closer proximity to a shore-line than that in which the beds were deposited in the main Waipara, the Weka Pass, or the Cass Range areas. The fact that the sequence is unbroken in what appears to be a shallow-water facies, where one would anticipate breaks, supports the contention that the deeper-water beds are conformable.

Gore Bay.

An interesting locality is Gore Bay, near Cheviot, where sections are well exposed on the cliffs along the shore and on the southern side of the gorge which the Jed River has cut along the line of junction of the greywackes and the overlying Cretaceous and Tertiary beds. These latter are bent up into a well-marked syncline, which forms such a characteristic feature of the cliffs behind the sandhills of Gore Bay. Faulting is common, and on the southern wing of the syncline this has resulted in considerable crushing and brecciation along the belt of movement; nevertheless the relations of the beds are clear. The Amuri limestone in its typical facies is somewhat thin in this locality—about 12 ft.; but there is an underlying succession of marls with interstratified sandstone which is no doubt the equivalent of the lower part of the Amuri limestone at Kaikoura and other localities farther north and in the neighbourhood of Weka Pass. The upper surface shows a characteristic junction, with phosphatic nodules, succeeded by a calcareous greensand, the probable equivalent of the Weka Pass stone. (See Hutton, 1885, p. 271, for a similar occurrence near Stonyhurst.) There is no evidence, however, of an unconformity, the sequence throughout being entirely regular. The following is a detailed description of the occurrence in a deep washout in the cliffs about a quarter of a mile north of the disused landing-stage at Port Robinson. The beds are much crushed, but their relations in the vicinity of the line of junction are clear and characteristic. (Plate VI, fig. 1.)

Amuri Limestone.—The typical portion is about 12 ft. thick, but it is underlain by greyish marl. Borings begin about 3 ft. below the upper surface, but they increase in number till the contact is reached. The cavities are filled with greensand.

Nodular Layer.—This is 6 in. to 8 in. thick. The nodules are in a matrix of greensand, some being of phosphatized limestone, the other more characteristic ones varying in colour from light green through olive-green to dark green and black.

Calcareous Greensand.—This is the probable equivalent of the Weka Pass stone. It is strongly calcareous, and contains nodules sporadically up to 3 ft. above the junction. Some of these have the external appearance of greywacke but are distinctly phosphatic, and are dark green in colour. They are up to 2½ in. in diameter, but numbers of them are small.

An exactly similar section occurs on the north wing of the syncline where the road comes down on to the beach near the old lime-kiln. This locality is also noteworthy since the limestone contains abundant nodules of flint. There is no evidence of unconformity. A similar junction occurs on the steep scarp facing the Jed River, but farther north-west, on the south side of the road leading to Cheviot, we were unable to locate it definitely owing to the covering of grass where the loose greensand had been removed; but the borings in the limestone were noted in various places, so no doubt a similar contact exists there as well.

South Bank of the Hurunui.

On the south bank of the Hurunui, half a mile up-stream from the lowest bridge and about a mile from the sea, the whole series from the greywacke upwards is clearly exposed on the river-bluffs. The section consists of the following:—

(1.) *Sands.*

(2.) *Amuri limestone,* over 50 ft. thick, with a north-and-south strike, and a westerly dip of 10°. It is of the usual character, the upper 4 ft. perforated with borings, the cavities filled with greensand. Included in the limestone are lenticules of greensand, and in the uppermost 2 ft. this condition is more pronounced, typical green nodules occurring sporadically.

(3.) *Nodular layer:* This is 6 in. in thickness, the nodules being dark green to brown in colour, up to 2 in. in diameter, subangular, the whole layer being densely compacted with greensand cement.

(4.) *Calcareous greensand,* soft, very glauconitic, and containing nodules scattered through the lower 2 ft.

(5.) *Calcareous greensand,* 30 ft. thick. A fragment of coal 3 in. in length and 1 in. thick, lignitic in character, was noticed in this bed.

The section is closed by brown sands. Parts of the section are faulted, but where there is no evident disturbance the conformity is clearly displayed. Especially is this the case on the river-cliffs. In a cutting on the road in close proximity water-worn pebbles of greywacke are apparently involved near the junction, but they also occur in greensand 2 ft. above the junction; the occurrence is only a few feet in length, quite local, and, as the rocks show disturbance, may be attributed to fault or slip movements, since no similar phenomenon was observed elsewhere.

On Coast South of the Blyth River.

This section can be seen near the top of the magnificent limestone cliffs which form the background of the Napenape beach, one of the finest coastal scenes in New Zealand. Here old shore-platforms with beach-gravels on top occur at a height of 500 ft. The sequence exposed is as follows:—

(1.) *Amuri limestone:* This strikes north-east, and dips south-east at low angles; it is probably affected by slight local folding, but, owing to slipping, the precise direction is difficult to determine; its thickness is at least 300 ft. The rock is beautifully white, compact in texture, jointed in typical fashion, but much disturbed by slips and faults owing to erosion of the shore and to natural fractures. A small mollusc shell was found in the upper layer, which has been identified by Mr. Suter as a variety of *Pecten williamsoni.*

(2.) *Greensand layer:* This is loose, calcareous but strongly glauconitic, 8 ft. thick, without nodules as far as could be seen on the face of the steep cliff, and passing up into

(3.) *Glauconitic arenaceous limestone*, 12 ft. thick, resembling Weka Pass stone but rather more sandy.

(4.) *Grey marl:* This succeeds (3) with perfect conformity. Its thickness cannot be estimated, since the highest shore-platform has been cut in it.

The upper layer of Amuri limestone contains borings filled with greensand, and the marl also contains borings filled with marl.

Stonyhurst, in a Creek near the Homestead.

This place was visited in order to obtain observations of the section recorded by Hutton (1885, p. 271). It is unfortunate that he does not give the precise locality, but a careful examination of the creek in the neighbourhood of the station showed that only one section in the course of the stream was possible, and a description of this is given below. Hutton's remarks are, however, very important. He says, "Here the Amuri limestone is overlain by grey sandstone, probably the representative of the Weka Pass stone. Between the two rocks is a bed of conglomerate formed by subangular pebbles of slate. At first sight all three appear to belong to one system, but a close inspection shows that the surface of the limestone is fissured, and that the sandstone penetrates through the conglomerate into the limestone. This, however, may be due to chemical erosion."

The special importance of these remarks is that they contain a record of pebbles of greywacke along the junction; it is extremely likely that these pebbles are phosphatic nodules, since at times the latter closely resemble greywacke in external appearance. It is unfortunate, therefore, that Hutton's precise locality cannot be determined.

In the creek near the homestead the beds lie very flat, and are obscured by surface accumulations and vegetation. At one place a clear section was seen, the only one occurring in the creek. Its record is as follows:—

(1.) *Typical Amuri limestone*, striking north-east, and dipping south-east at an angle of about 25°.

(2.) *Nodular layer*, 6 in. thick, with the usual characters.

(3.) *Calcareous greensand.* This passes up into

(4.) *Weka Pass stone* of more than usually glauconitic character.

The locality is disturbed by faults, but away from the disturbance the dip and strike of the Amuri and greensand limestones are identical.

Motunau River.

An excellent section through the whole series is to be seen in the lower course of the Motunau River, and the limestones are well exposed in its limestone gorge about two miles from the sea. The beds strike here north-north-east, and dip east-south-east at an angle of 20°, the whole being absolutely conformable. The sequence is as follows:—

(1.) *Amuri limestone*, with typical macrostructure, its estimated thickness being 300 ft., the upper 4 ft. with borings filled with greensand.

(2.) *Nodular layer*, 3 in. to 4 in. thick, composed of subangular nodules in a matrix of greensand; the nodules are up to 3 in. in diameter, dark-blackish-green in colour, with brown shade inside (? Hutton's greywacke pebbles).

(3.) *Greensand*, 25 ft. thick with sporadic nodules in the lowest 2 ft., more thickly distributed near the junction. This passes up with occasional more marly or arenaceous layers into arenaceous limestone (Mount Brown limestone); passage beds are well developed along the junction.

Boundary Creek.

Boundary Creek, which lies midway between Stonyhurst and Motunau, was also examined, since McKay (1881, p. 111) records a good section there. The exposure was found to be very unsatisfactory owing to slips, although probably it was in better condition when McKay described it nearly forty years ago. The Amuri limestone appears to be about 20 ft. thick, but the exact contact with the overlying beds is not visible at present. Large blocks of greensand also occur in the bed of the stream, showing plentiful subangular nodules similar to those in the Motunau, associated with borings filled with greensand, no doubt near the actual junction. McKay does not mention this greensand layer, and says that grey marls immediately overlie the Amuri limestone. Judging by the dip, the limestone is in a conformable position under the top beds of the series, which have a general synclinal arrangement with the eastern limb towards the present coast-line; but there are local variations in dip well displayed on the sides of the deep gorge which the stream has cut through the non-resistant sands and marls which close the Tertiary series in this locality. It is noteworthy that McKay considers the sequence below the Motunau beds to be perfectly conformable, although he places a stratigraphical break immediately at the base of these beds, a conclusion which appears to us not warranted by observations of dip and a general examination of the section both here and in the Motunau River. The similarity of the sections in the two localities is most marked, and the evidence available from one supports that from the other.

South Side of Amuri Bluff. (Plate VI, fig. 2.)

The Amuri limestone is much jointed into flaky quadrangular blocks something like a tiled roof; it strikes north-east, and dips south-east 30°. The top 4 ft. are bored through and through with tubes which are well filled with calcareous greensand, the phenomena being progressively more marked as the upper surface is reached, where the rock is completely honeycombed and the fragments are detached. These are from 1 in. to 3 in. in diameter and are also completely bored. From this level upwards the pebbles decrease in importance and the greensand increases. All through the greensand layer nodules occur, which become smaller in the upper portions; the thickness of the greensand layer is about 2 ft., and the nodular portion where the structure is most marked is about 1 ft. thick. Above the greensand layer the rock passes gradually upward for about 3 ft. into typical Amuri limestone. The nodules of the upper layer are markedly phosphatic, while those of the lower layer are only slightly so; the phosphatization apparently diminishes progressively from the nodular layer. There are numerous sharks' teeth and occasional bones (? whale-bone) in the nodular layer.

On Bluff North of the Mikonui Creek.

The bed is exposed on the face of the cliff immediately to the north of the point where the track rises over the shoulder of the spur to escape high tides. Here we have the following sequence: First, typical Amuri

[T. Fletcher, photo.

FIG. 1.—Contact of Amuri limestone with greensand layer containing phosphatic nodules, Port Robinson. A small fault is also apparent.

[R. Speight, photo.

FIG. 2.—Nodular layer in Amuri limestone, south side of Amuri Bluff. The parallelism of the layers is very marked.

[R. Speight, photo

Fig. 1.—Nodular layer in Amuri limestone, Maori village, Kaikoura Peninsula. The dark, flat surface marks a fault almost parallel to the strike.

[R. Speight, photo.

Fig. 2.—Nodular layer in Amuri limestone, Atiu Point, Kaikoura Peninsula. Note the parallelism of the beds.

limestone, followed by greensand with inclusions of Amuri limestone, 5 ft. thick in one place, and containing distinctly angular, black phosphatic pebbles. In some parts of the contact the Amuri limestone has inclusions of greensand, the latter being in relatively small amount. This is succeeded by 12 in. of nodular layer of the usual type, and followed then by glauconitic limestone with small green nodules and black nodules. As the band is traced north and south from the point under consideration the greensand is not so prominent but is mixed with Amuri limestone, which is especially glauconitic on or near the junction.

Near Maori Village on South Side of Kaikoura Peninsula. (Plate VII, fig. 1.)

The contact is well exposed in this locality on the raised shore-platform which covers a large area on the south side of the peninsula. The following sequence in ascending order occurs here :—

(1.) *Amuri limestone*, of the usual type, but rather more flaky than jointed, perhaps the effect of faulting.
(2.) *Fault*, almost parallel with the strike, with a small but increasing throw when followed to the south-west.
(3.) *Calcareous greensand* from 8 in to 10 in. thick, showing honeycombed borings filled with glauconitic limestone, together with masses of greensand of irregular form. The lower part is filled with cavities, some of the worm-bored type, while others are much larger and irregular in form, the whole being filled with a uniform type of calcareous greensand. In the upper portion the worm-casts and greensand masses are smaller.
(4.) *Nodular layer:* The nodules are green and black, and the structure is very well developed, so that the intervening spaces are small. These are filled with calcareous greensand.
(5.) *Glauconitic limestone*, 4 in. to 5 in. thick.
(6.) *Greensand*, ½ in. thick.
(7.) *Glauconitic limestone*, rather more glauconitic than (5), 5 in.
(8.) *Greensand*, 1 in.
(9.) *Glauconitic limestone*, more glauconitic in the lower layer but passing up into one which is less glauconitic, 10 in.
(10.) *Limestone*, of Amuri type, with flints, 6 in.
(11.) *Glauconitic limestone*, with only a small amount of glauconite.
(12.) *Amuri limestone* as typically developed, 120 ft. in thickness.

This section shows no sign of unconformity.

North of Atiu Point, East End of Kaikoura Peninsula. (Plate VII, fig. 2.)

The contact is well displayed in this locality on the shore-platform at the base of the cliffs and on the cliffs themselves. The following is a description of the beds in immediate proximity to the contact :—

(1.) *Amuri limestone.*
(2.) *Calcareous greensand:* The rock is bored in the usual manner and the interstices filled with calcareous greensand, and becomes more glauconitic upwards, and contains nodules green in colour, irregular in shape, up to ½ in. in diameter. This merges gradually into the nodular layer.
(3.) *Nodular layer*, consisting of phosphatic nodules, more continuous than usual, the progressive development being more marked, the nodules being in a cement of calcareous greensand.
(4.) *Limestone*, 2½ in. thick, with nodules in small number.

(5.) *Calcareous greensand*, 2½ in. thick, well bedded.
(6.) *Glauconitic limestone*, 8 in.
(7.) *Greensand*, 3 in.

Above this there are regularly distributed layers of calcareous greensand and glauconitic limestone throughout the next 3 ft. above the nodular layer, and this is followed by

(8.) *Amuri limestone*, with flints, the lower 10 ft. of which is bedded in layers which are more or less glauconitic, which finally passes up into typical stone striking north-west, and dipping south-west 10–15°.

All the layers of this sequence are much folded, the intensity of the deformation being of the same order in each case.

The same beds are seen on two other cliffs north of Atiu Point where the strata strike almost parallel to the shore-line but with acute minor folding. The nodular bed is 8 in. to 10 in. thick, with the same general features as before; the greensand layers are, however, between thicker beds of limestone above, but underneath are the same as usual.

The nodular layer also occurs on the shore-platform in this locality, but is much contorted and separated by faulting from the main layer.

North Side of Kaikoura Peninsula, on the Shore-platform between the Old and New Wharves.

This occurrence has not been noted previously, as it is somewhat difficult to locate. The limestone in which it occurs is much folded and contorted, but where the contact occurs the strike is north-east, and the dip south-east at an angle of 50°. The following is the sequence as here shown:—

(1.) *Amuri limestone*, flaky in general, but subschistose occasionally owing to the movements of the beds, and with crystalline texture. The upper 6 in. of the limestone contains a considerable amount of flint, some of which contains calcareous greensand in borings, an extremely important point bearing on the origin of the flint.
(2.) *Nodular layer*, 6 in. thick, with nodules in a glauconitic matrix but less rich in nodules than usual, and succeeded by
(3.) *Glauconitic limestone* and *calcareous greensand* in alternate layers, the former 3 in. and the latter ½ in. in thickness. The lowest 3 ft. contain small and typical green phosphatic nodules. Thereafter the layers of glauconitic limestone are thicker, but still alternate with narrow bands of calcareous greensand to a depth of 20 ft. to 25 ft. It should be noted that at one spot three angular pebbles of basalt 2½ in. in diameter were found. These may have been of contemporaneous origin, but more likely were embedded at a later date, as others were found loose.

Mouth of Lyell Creek, Kaikoura.

The contact of the typical Amuri limestone with the overlying stone of the Weka Pass facies is to be seen close to the mouth of Lyell Creek on the northern side of the Kaikoura Peninsula. It is on the western wing of the anticline which forms the main mass of the peninsula. The beds strike here east-north-east, and dip north-north-west at an angle of 20°, the agreement between the two facies of the rock being complete.

The following is a description of the contact as far as it can be seen; at the time of our visit it was unfortunately partly obscured by a covering of beach shingle.

The underlying beds are of Amuri limestone as typically developed, very white, with flaky jointing and nodules and masses of flint, and with borings filled with greensand. Over this lies, with the intervening beds obscured by gravel, a glauconitic limestone, with inclusions of Amuri limestone which is decidedly phosphatic, the thickness being uncertain but certainly not more than 3 ft., the upper portion containing more of these than the lower part. It is succeeded without any unconformity by a much more glauconitic limestone—in fact, a greensand—from 6 in. to 8 in. thick, containing borings, and also small, dark, oxidized nodules. This is followed by a glauconitic limestone, also with nodules, which become smaller and smaller in the higher levels. The glauconitic character is very marked, with a concentration of the glauconitic material in well-defined layers; and borings filled with more highly glauconitic material occur throughout the whole thickness of the bed. This is succeeded in about 30 ft. (?) by the ordinary type of Amuri limestone, which very occasional glauconitic layers. No flint was observed in the upper part of the limestone. The whole section is strongly reminiscent of that at Weka Pass.

Puhipuhi Valley and Long Creek.

The limestone up the Puhipuhi Valley and that occurring up Long Creek on the southern side of the Hapuku River were also examined in order to see if any similar horizon occurs marked with phosphatic nodules, but with unsatisfactory results. The best exposure that was encountered was in a cutting just past the bridge over the Clinton River, a similar junction, somewhat obscured, being observed in the gorge of the Clinton River itself. The beds in this locality are much folded, and have suffered crushing as a result of folding and faulting movements, so that their stratigraphy is not clear. In the road-cutting to the north of the bridge the beds strike east-north-east, and dip north-north-west at an angle of 60°. The ordinary Amuri limestone is succeeded by layers of calcareous greensand, the layers being more or less glauconitic through about 15 ft., some being distinctly greensand. This is succeeded by hard greyish-green arenaceous limestone, well jointed, and with bands of more greenish tint running through it. It is much crumpled and faulted, and at least 70 ft. thick, and passes up into layers of more arenaceous character. This limestone is decidedly phosphatic. There is a strong similarity to the beds exposed some ten miles away at Lyell Creek, but no nodules of phosphatic nature were met with. Although they are apparently absent, it seems quite reasonable to maintain that the junction is on the same horizon. There is no evidence of unconformity.

Contact of the Grey Marl with the Underlying Limestone.

Although discussion of this contact is not directly connected with the principal subject of this paper, it has some bearing on the question, and therefore a description of all the contacts noted is here included. As the grey marl is easily eroded and apt to weather readily into soil, good exposures are rare. Those examined, however, show certain features which resemble the contact of the Amuri limestone and the Weka Pass stone, notably the bored upper surface of the limestone and the presence of detached fragments of the lower layer included in the higher, and it seems reasonable that if unconformity is demanded in one case it must also be demanded in the other. A consideration of the following sections will illustrate our contention as to similarity of evidence.

Main Branch of Weka Creek.

This section occurs in the main branch of Weka Creek, below the small bridge on the road from Weka Pass in the direction of the Waipara River to the north-west of the Deans Range. The junction between the Weka Pass stone and the overlying marl is well seen in the bed of the creek and on the sides of the deep but narrow gorge where the road crosses. The agreement in dip is absolute, and the contact does not show any signs of unconformity. The Weka Pass stone exhibits on its upper surface the same kind of borings which mark the contact of the two limestones, but the bored zone is narrower. This is succeeded by 1 ft. of slightly glauconitic sandy marl, then by 12 ft. of slightly glauconitic sandstone, passing up into sandy marl and becoming more argillaceous higher up but still preserving something of its arenaceous nature.

Near Old Wharf, North Side of Kaikoura Peninsula.

The upper surface of the Amuri limestone is tily in character, as at Amuri Bluff, with lenticules of grey marl included in the limestone, as also there are inclusions of limestone in the grey marl, the inclusions being more phosphatic than the limestone and marl in general, which are practically free from phosphate. The marl is decidedly glauconitic near the contact, and presents all the features of a fine-grained glauconitic sandstone, the sandy facies extending for 10 ft. or 12 ft. above the contact. The contact is conformable stratigraphically, any divergence from a normal junction being due to folding or faulting.

East Side of Kaikoura Peninsula.

The general strike of the beds is north-east. The Amuri limestone is much contorted, brecciated by folding, faulted, and, as a result of these structural movements, crystalline in many parts and at times subschistose in appearance. The grey marl is folded on the same lines, and sometimes included in the limestone as a result of folding. The grey marl has been subjected to just the same intensity of deformational movement as the limestone, but it exhibits the results of these movements to a much smaller degree except at the immediate contact with the limestone, where it is subschistose in structure. The whole locality exhibits faulting, some of the major faults running north-north-east parallel to the general trend of the coast-line of the Island, but there are numerous others crossing at right angles, so that the whole locality may be described as a complex of faulted anticlinoria and synclinoria, but wherever the junction between the marl and the limestone is clear the junction is conformable. It might be noted here that Hutton's figure of the East Head (1885, p. 273) is entirely incorrect.

On the south side of the peninsula, near the Maori village, the contact is of the same character as on the north side. The Amuri limestone is slightly glauconitic, becoming more so near the junction. There is a layer about 6 in. thick where the limestone and the marl are mixed, a phenomenon which is in part due to boring. The grey marl is glauconitic in its lower part for a thickness of several feet, and contains numerous fragments of whale-bone. Along the line of contact faulting is much in evidence, the faults being both normal and reversed, with a direction in general at right angles to the strike. The figure by Hutton (1885, p. 273) is evidently given under a misapprehension of the effects of faulting, the irregular line of contact being attributed by him to erosion.

South Side of Amuri Bluff.

In this locality the sequence is well exposed on the finely developed shore-platform on the south side of the bluff and around the coast-line as far as the mouth of the Okarahia Creek. Above the nodular layer there is about 15 ft. or so of limestone, and this is succeeded conformably by a greenish calcareous sandstone, perhaps the equivalent of the lower part of the typical grey marl, or perhaps, as is more likely, the equivalent of the Weka Pass stone. The upper portion passes into a typical marl of decidedly argillaceous character. Hutton considered that this locality furnished strong evidence of unconformity between the grey marl and the Amuri limestone, his main line of evidence being the discordance in the dip of the former as it occurs in the neighbourhood of the mouth of the Okarahia Creek and south of it with the limestone at the bluff. This apparent discrepancy in angle of dip is due to folding and twisting movements affecting the beds unequally in the two localities. The limestone south of the creek dips at a very high angle, and the marl is in perfect accord with this; while when traced in a north-easterly direction towards the bluff the beds flatten out, and nowhere present any evidence of discordance.

Evidence that the Series is Conformable.

This detailed account of the sections taken from widely separated parts of the area gives some idea of the general nature of the contact and emphasizes the similarity of its features. Relying entirely on the evidence of the borings in the upper surface of the Amuri limestone and the presence of detached fragments of the limestone in the greensand matrix of the nodular layer, Hutton and Morgan came to the conclusion that it was a true erosion surface, the supposition being that the erosion took place in the vicinity of a shore-line. No palaeontological evidence was advanced by either in support of their contention as regards the two limestones, the reason being that they are both, the Amuri limestone especially, according to Hutton, almost unfossiliferous; thus in their opinion the existence of an unconformity rests entirely on stratigraphical evidence. We, however, relying on stratigraphical evidence, have come to a conclusion that the sequence is conformable, the reasons for this conclusion being as follows:—

1. In every case there is absolute agreement in the dip of the beds above and below the nodular layer. When this occurs over a region of a hundred miles in length by some fifteen in breadth, unconformity appears extremely doubtful. It means that a limestone has been laid down on a deep-sea bottom, the rock has become consolidated, raised above the sea, eroded, and again depressed into deep water so that another layer of calcareous material may be deposited, and all this without any variation in angle due to structural movements or to conditions of deposition over hundreds of square miles. Such a contention appears unreasonable.

2. Apart from the evidence furnished by the included fragments of limestone in the nodular layer, and the report of the occurrence of pebbles of greywacke at Stonyhurst, which can be explained as probably the result of mistaken identification, there is no evidence of erosion of the upper surface of Amuri limestone. On any present-day surface of Amuri limestone there are distinct irregularities, and especially is this the case on the shore-platforms where tidal channels, &c., are a marked feature, and none of these are to be seen at any part of the contact, although it is exposed for many miles in different parts of the area, not only parallel but at right angles to

the present shore-line. It would be expected that they should occur somewhere. Present-day shore-lines show surfaces of Amuri limestone with no similarity whatsoever to those associated with the nodular layer, even when those parts of the shore-platform are composed of nearly horizontal layers. Any change in the nature of the rocks due to folding and consequent induration which might be cited from the Kaikoura neighbourhood as modifying the conditions would not apply farther south, where the influence of such movements has been comparatively slight.

3. There is no true shore or shallow-water deposit of any kind over the whole area. It is certain that during the depression demanded by the unconformists, when the surface of the Amuri limestone was lowered from forming part of a land surface or a shore-line to such a level that glauconitic limestone and greensand were deposited, beach and shallow-water beds would occur in some parts of the area. Nevertheless they are absent entirely.

4. In many places is it impossible to determine the dividing plane between the two limestones, so gradual is the transition—that is, they furnish in some places no evidence of a break. In fact, as a general rule the upper and lower layers display such a similarity in their characters, notably in the presence of glauconite, that transitional forms are to be expected.

5. In the case of the borings in the upper surface of the Amuri limestone, and also those in the Weka Pass stone in contact with the grey marl, the borings are filled with the material of the overlying bed, however deep they are down below the surface. If this is a greensand the tubes are filled with greensand, if a marl they are filled with marl. Also, there are cases of tubes in the body of the limestone which are filled with the material being laid down on the surface into which the borings were made. If, now, these borings were made on an ordinary beach or shore-platform they would be filled with beach deposit, and would not remain open till they were depressed to a depth at which limestone or greensand was the characteristic deposit.

6. The remarkable uniformity in the thickness of the layer over long distances appears to be inexplicable on the basis of its being a shore-line deposit, since these are notably variable both in thickness and in the nature of their constituents. The parallelism of the upper and lower surfaces of the layer is well brought out in the photographs taken from various widely separated localities where the bed is well and clearly exposed.

7. The analyses of the so-called "rolled pebbles" at the junction between the two layers (see page 71) shows that they are not ordinary detached fragments of Amuri limestone such as would be found on a beach, which should resemble the parent rock in chemical composition. They have certainly been modified by agencies other than those operating on a shore-line.

Morgan (1915, p. 92) cites a paper by Edward M. Kindle on "The Unconformity at the Base of the Onondaga Limestone in New York, and its Equivalent West of Buffalo";* and remarks, "This paper describes fully an unconformity not easily detected at all points by stratigraphical evidence alone." He uses it to emphasize the fact that an unconformity can occur between two limestones. But it seems to us that such contacts are by no means unlikely, since limestones of various ages form a notable feature of the rocks of the earth's crust, and the probability of a contact between two limestones as compared with that between limestone and

* *Journ. Geol.*, vol. 21, pp. 301–19, 1913.

another rock of different lithological composition is in proportion as these rocks form part of the earth's crust in the locality where the limestones are being laid down. The criteria of unconformity in general, apart from the possibility of chemical erosion on the plane of contact, will be the same as between limestone and another rock. In Kindle's paper attention is drawn to the difference in dip of the two limestones in question, and to the decided surfaces of erosion of the lower limestone. The photographs that he uses to illustrate his paper are quite convincing, and show pronounced differences in the contact as compared with that between the Weka Pass and Amuri limestones, and we have seen no locality where similar pictures could be obtained from the contact of the two New Zealand rocks.

For the reasons given above the authors consider that the contact between the two limestones is not due to erosion, and that after the deposit of the lower bed no emergence from the sea took place before the second limestone was deposited. Some alteration in depth or in the conditions of deposition no doubt occurred, but they were of no greater amount than that which takes place when a bed of different lithological character is laid down in a perfectly conformable sequence.

It has been pointed out that both above and below the nodular layer there is an interstratification of greensand in the limestone, the deposition being conformable, which shows that slight oscillations of level or conditions took place. The phosphatic nodules are exactly analogous to those forming now on ocean-bottoms at depths of over 100 fathoms in association with greensand, and such do not form on a shore-line. Such nodules are frequently found in the Cretaceous limestones of Europe and America without an unconformity being demanded, although some lapse of time and change of conditions must have occurred. The phosphate nodules occurring in the Cretaceous beds of the south of England and the north of France and in Belgium usually lie at the base of the series which succeeds another after some lapse of time. In some cases, however, distinct unconformity has been demonstrated on account of the presence of pebbles and rolled fossils, the break being of more decided character and amounting to an unconformity, but in other cases there is no pronounced break.

The association of these nodules with a bored surface seems to indicate clearly that the boring took place not on a shore-line, but on a sea-bottom formed of a soft calcareous ooze before it had consolidated and hardened into rock. The borings extend to such a depth beneath the surface that it may be doubted whether it is possible for marine organisms to tunnel such a distance into hard rock, whereas if it be admitted that the boring took place before the rock had consolidated and while it was actually in process of deposition there is no difficulty. The filling of these deep tunnels with greensand, as has been pointed out, certainly suggests boring on a sea-bottom. Although many marine organisms have the power of making burrows, it occurred to us that they were in all probability made by marine worms, and therefore we applied to Dr. Benham for his opinion on the matter. In a private letter he says, "Unfortunately we know nothing, so far as I can find out from monographs on the Polychaeta, &c., about the burrows in deep water. When the dredge is used the surface of the mud, &c., will still be disturbed; and even if the worms are captured the walls of the burrows, if any, will fall in, and the burrow, of course, will be smashed. So that I find no reference at all to burrows of worms living beyond the littoral-zone area. But we may expect that if they are formed at these greater depths they, too, will be U-shaped. You ask at what depths worms live

and work. Certain species have been found at as great a depth as 3.000 fathoms, though at depths below 1,000 fathoms they are much rarer than at less than 100 fathoms—that is, the great majority live along the continental shelf, and especially along the littoral area."

This opinion is not conclusive, but it certainly indicates that it is possible for worms to produce borings at the depth at which greensand is deposited.

The statements of Cayeux (1897, pp. 431–32 and 532–33) are of interest in their bearing on this point. He shows that phosphatic nodules occur in ths chalk of France and Belgium at levels marked by change in the depth of the sea, whether this be in the direction of increasing or of lessening depth—that is, they occur at the points of inflexion of the curves indicating the depths of the sea over the area at any particular time. He says (p. 431), "La production du phosphate de chaux de la base de la craie à Belemnitelles correspond à une rupture d'équilibre de la mer crétacée, phénomène dont on a maintes preuves." These are then given, and among them may be noted the hardening of the upper layer of chalk and the presence of perforations. The first of these is perhaps analogous to the hardening of the fragments in the upper layer of Amuri limestone which may be attributed to phosphatization, and the second is a most characteristic feature of its upper surface. Farther on (p. 432), he says, "La craie phosphatée du department du Nord est en relation avec un mouvement d'exhaussement qui a eu pour résultat de chasser la mer du golfe du Mons. Son existence est liée à une période de régression de la mer pour le Nord." Of the two instances quoted, the former applies to an increase in depth of the sea and the latter to a diminution in depth. The latter in all probability is analogous to the change from Amuri limestone to calcareous greensand which characterizes the level of phosphatic nodules in the New Zealand area.

Further, Cayeux considered that the accumulations of phosphatic material took place at such a distance from the shore that the change in depth of the sea did not permit of any marked variation in the character of the terrigenous material associated with the chalk. This is borne out to some extent in the area under consideration, as it has been shown that the material of the phosphate nodules is not markedly different from that of the beds with which they are associated. In any case, Cayeux does not postulate any emergence of the sea-bottom to account for phenomena which are quite analogous to those near the junction of the Amuri and Weka Pass limestones.

The Peculiarities of the Junction of the Amuri Limestone and Weka Pass Stone.

It must be admitted that the junction of the Amuri and Weka Pass limestones is a peculiar one and demands some special explanation, seeing that unconformity is not admitted. The irregularity of the junction in some places could be attributed to chemical erosion, and the increased amount of phosphate in the detached pieces of Amuri limestone in the nodular band supports this contention; but it may be explained in another way, or perhaps the two explanations are not mutually exclusive. It seems to us that the so-called erosion surface has been the result of extensive boring during the interval between the deposition of the typical Amuri limestone and the upper more glauconitic part of the bed when it formed part of a sea-bottom. As a result of the complete penetration by borings the upper surface consists in places of peninsulas of limestone surrounded by green-

sand. In places, too, these jutting portions have been completely cut off, so that they become detached fragments. Similar occurrences can be seen at times in the estuaries which are filled with calcareous mud and have been completely honeycombed by borrowing molluscs, &c. In this way an apparent erosion surface can be formed; but the character of the junction under consideration requires a uniformity of conditions over wide areas, and this would be obtained if the bored surface were a sea-bottom and not a shore-line. The increased phosphatization of the fragments of Amuri limestone, and perhaps of the true phosphatic nodules, might be accounted for by the decay of the bodies of the boring organisms, in addition to probable increased phosphatization owing to concentration by the dissolving-out of the more soluble calcium carbonate from the rock.

The remarkable persistence of the nodules of phosphatic material at a limited level in the limestone renders them extremely useful as a datum-level for comparing the relative age of rocks in the series, and this is all the more valuable owing to the comparative absence of fossils. It may, of course, be suggested that there is more than one layer in the limestone, and that the phosphatic nodules at Kaikoura occupy a different position from those at the Weka Pass; but the whole of the attendant circumstances of the surrounding beds renders it extremely likely that only one layer exists. If the nodules had been laid down on the bed of a deep sea, then it is likely that the sea extended all over the area in question, and their synchronous formation would be very probable indeed.

Assuming that this is so, it would clearly indicate that the Weka Pass stone was the equivalent of the upper part of the Amuri limestone in the Kaikoura district and also at Amuri Bluff; but, seeing that the lower portion of the grey marl at Kaikoura and Amuri Bluff is lithologically a calcareous greensand, it is not at all improbable that Hutton was partly correct in correlating the Weka Pass stone with the grey marl, only that it is the lower portions of the marl that are equivalent to the upper layers of the Weka Pass stone. However, between the marl and the limestone in the Kaikoura region there is a junction which is analogous to that between the two limestones, in that the limestone immediately below the lowest layer of the grey marl is bored and sporadic phosphatic nodules occur in it. This, of course, indicates some break in time.

At the Amuri Bluff the thickness of the limestone above the nodular band is reduced to 15 ft. as compared with a thickness of 100 ft. or more at Kaikoura and a great thickness as exposed on the sea-cliffs between the Oaro and Mikonui Creeks. It must be mentioned, however, that as the beds are traced along the coast south of Amuri Bluff towards the Conway River they thin out and the limestones lose their distinctive features. This certainly suggests the vicinity of a shore-line, and therefore there is no improbability that the lower part of the grey marl in that neighbourhood, especially that part with sandy texture, may be the stratigraphical equivalent of the glauconitic facies of the Amuri limestone farther north, the sea evidently deepening in a northerly direction. It is probable that an easterly extension of the land, either continuous or in the form of islands, divided the Kaikoura part of the sea from that south of the Hurunui. The existence of such a land if it were of low relief would not, of course, negative the contention that a sea extended generally over the site of the present Kaikouras, and that the land had been base-levelled to some extent before being depressed and covered with a veneer of Tertiary sediments. But it must be clearly understood that the shore-lines of this land must not be con-

sidered as related to the present orographic features. These are, no doubt, a very late development, as demanded by McKay and by Cotton. The failure to appreciate this point thoroughly no doubt influenced Hutton, and to some extent Morgan (1916, p. 28), in attempting to fix the position of the shore-line of the Tertiary sea in that region.

Since we maintain the conformity of the two limestones, and since we can suggest no other horizon where a physical break occurs in the series under consideration, our present contention involves the recognition of the stratigraphical conformity of beds in the lower part of the sequence containing Cretaceous fossils with those higher containing Tertiary fossils. (For the latest pronouncement on the Cretaceous age of the lower members of the series see Trechmann, 1917, p. 295.) In our opinion the beds with Cretaceous fossils are definitely Cretaceous, and those higher up with Tertiary forms are Tertiary. The anomaly is accounted for by the slow and continuous deposition of the beds, so that when the period of deposition commenced the time was Cretaceous, and when it closed it was Tertiary, judging by European standards of geological time. The earlier part of this period was marked by slow depression of the land, with a corresponding change in the nature of the deposits (see Speight, 1917, pp. 350–51). During the time of maximum submergence the greensands and limestones were deposited, and as the sea-bottom was raised a reversal of the order took place with slight minor oscillations. When one considers the small area of land which was probably in existence above sea-level in the vicinity of the region under consideration, the slow rate of deposition can be readily understood. Thus during this long period of submergence of the area the local fauna had time to change from a Cretaceous to a Tertiary facies.

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ART. VI.—*Structural and Glacial Features of the Hurunui Valley.*

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THE Hurunui Valley is one about which little has been said in geological literature, though it is one of the most interesting of the main river-valleys of Canterbury, not only for its structural pecularities, but also for the glacial features of the country in the vicinity of its headwaters. The comparative neglect is perhaps due to the relative inaccessibility of its higher parts owing to the absence of roads, though before the discovery of Arthur's Pass it was the recognized route from Canterbury to Westland, while the lower portions were, till the opening of the Cheviot Settlement and the completion of the Waipara–Cheviot Railway, quite off the main lines of communication.

In 1865 Haast made a journey up the river across the island, an account of which is given in his *Geology of Canterbury and Westland* (1879), including a general description of the chief landscape features of the upper part of the basin. In 1871 he visited the middle Hurunui, and furnished a report (1871), in which he referred to the basin of the Mandamus, the main northern tributary of the Hurunui. Hutton (1877, pp. 34, 35; 1889) also gave some account of the locality, and dealt with the origin of the Hurunui Plains (1877, pp. 55, 56). This is practically all that has been written on the features of the main valley, except a brief reference by myself (1915, pp. 347–48) to the formation of the Waiau-Hurunui intermontane basin. Of course, there is abundant reference to the country to the north and south of the river, such as the Pahau Valley, and to the interesting stratigraphical questions connected with the Waikari and Greta Valleys, but a consideration of these is foreign to the scope of this paper. It is intended to give an account of the general geology of the basin only in so far as it is connected with its peculiar structural and glacial features.

General Topography.

(See map, fig. 1.)

The chief stream of the Hurunui rises in the main chain of the Southern Alps, and flows east between bush-clad mountains whose height approximates between 5,000 ft. and 6,000 ft. till after a straight course of some eighteen miles it empties into Lake Sumner. This is a fine lake, seven miles long by one a half wide in its widest part, 1,724 ft. above sea-level. Thence the Hurunui flows south-east for about eight miles, and receives on the south a tributary almost as large as itself, called the South Branch, the main stream being sometimes called the North Branch. In this part of its basin are several small lakes, the most important being Lake Katrine (which is practically an indentation near the head of Lake Sumner), Lakes Taylor (1,914 ft.) and Sheppard (1,916 ft.) in a valley between the two branches, and Lake Mason in a side valley of the South Branch.

Below the junction of the two main streams the valley continues for nearly three miles in a south-easterly direction between somewhat precipitous mountain-sides, and then turns east and passes through a deep, narrow, picturesque gorge, locally known as Maori Gully, and believed to be the scene of an engagement between two Maori tribes in early days.

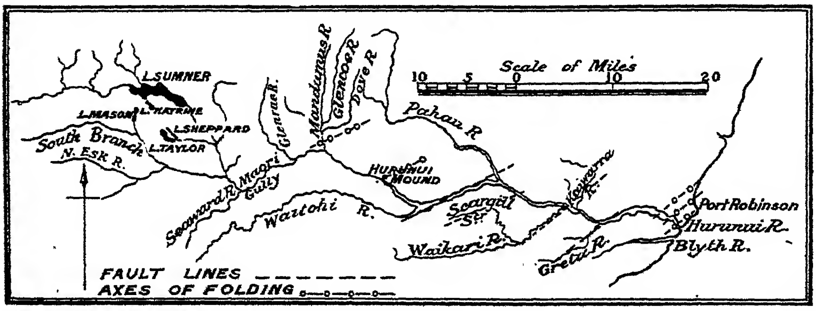

Fig. 1.—The Hurunui Valley.

The river then flows north-east for nearly ten miles through a hilly region in a narrow channel cut in the floors of detached basins and deeply incised in the ridges dividing them, till it reaches the Mandamus River.

Just below the junction with this stream the direction of the main river turns through a right angle and it enters the Hurunui-Waiau basin, flowing for about ten miles through an aggraded flood-plain till it receives the Waitohi on the south. It then makes a sudden turn and runs north-east along the southern edge of the Hurunui Plain, receiving the Pahau River on the north; but after a course of about eight miles it again breaks through a mountain barrier in a south-easterly direction and receives the Waikari River on the south and the Kaiwara Creek on the north, immediately after which it breaks through yet another mountain barrier and debouches into the Greta–Cheviot basin, across which it flows in a broad bed with terraced banks in an easterly direction till it discharges into the sea after cutting a somewhat deep gorge through a rocky bar just at its mouth.

The most striking feature of its course as a whole is the peculiar zigzag direction of the reaches which characterizes the middle part of its basin. These zigzags have alternate north-west and south-east and south-west and north-east arms, and it is their special relation to the grain of the country in some places and their absence of relation in others which is peculiar.

Basement Rocks of the Area.

The characteristic basement rock of the region is a greywacke such as is typically developed in the mountains of Canterbury farther south. This is usually of the hard grey facies, but slaty greywackes also freely occur, which break down under the weathering agencies into clay and form a covering on the mountain-slopes. On these forest once became thoroughly established, but it has been largely destroyed in the higher parts of the river-valley by the grass fires of settlers. The greywackes have a general north-easterly strike, with local variations. Beds of dark-red slaty shale also occur, as well as occasional outcrops of volcanic rock. Basalts and andesites occur near Lake Sumner on the Crawford Range, and there is in the Canterbury Museum a specimen from the same area marked " eurite " by Hutton. Basalt pebbles occur in the Seaward River, a tributary coming in from the south about three miles below the junction of the two branches, and similar rocks occur in position between it and the Waitohi River.

The most interesting occurrence is near the Mandamus. About a mile above its junction with the main stream a massive intrusion of augite syenite occurs in the greywacke. This has a general north-easterly trend, and it appears to have the character of a sill, being approximately parallel to the dip and strike. Its thickness is more than 200 ft., and it extends over a mile in length. Associated with it are trachyte dykes, and flows of augite andesite occur in close proximity. Hutton was of the opinion that the syenite represented the core of a volcano of which the andesite was the effusive representative. But angular fragments of the syenite are found in the andesite, in some places in considerable quantity, so that the intrusion of the syenite was evidently anterior to the andesite. We have therefore, in order of time, (1) greywacke, (2) syenite, and (3) andesites. In this district, too, there are basic volcanic tuffs having in their higher levels a calcareous tufa facies passing into a true limestone; but the volcanic beds are much better developed to the north-east, in the Pahau and Culverden districts, where there are interstratifications of volcanic material between beds of limestone. The occurrence at the Mandamus points to several periods of vulcanicity, the channel opened by the syenite affording a passage for later magmas.

Younger Rocks.

Volcanic rocks have exerted little effect on the area covered by the river-basin, in which greywacke is now by far the most dominant member; but at one time the lower parts of the valley were covered with a veneer of Tertiary sediments, remnants of which are still to be found. These later beds have all a north-easterly strike, so that they cut across the river at a average angle of 45°, and at present they occupy separate compartments of the valley, cut off from adjacent ones by ridges of greywacke. These isolated areas are as follows: (1) In the Dove River, a tributary of the Mandamus coming in on the east; (2) in the Hurunui-Waiau basin; (3) in the Waikari-Kaiwara basin, or rather trench; (4) in the Greta-Cheviot basin. The special features of these may be taken in turn.

(1.) *The Dove River Area.*

The Dove River basin is important, not from its size, but because it gives an indication of the origin of the landscape features of a considerable area of hill country forming a kind of platform or terrace at the base of the

higher region to the north-west. The Tertiary beds here consist of the following:—

4. Limestone, passing down into
3. Calcareous breccia with volcanic fragments.
2. Volcanic tuffs and ash-beds.
1. Sands with concretionary layers.

The lower parts of these probably contain coal, seeing that an adjacent stream is called Coal Creek. (See also Haast, 1871, p. 30.) The limestone is crystalline in texture, but shows traces of bryozoan forms on its weathered surfaces. The strata are bent up into a sharp syncline whose axis runs north-east, the remnant now existing being less than a mile in length and 300 yards in breadth. The underlying beds are naturally existent over a somewhat wider area, and extend across the Mandamus towards the Hurunui, the direction of one of the reaches of this stream corresponding in alignment and direction to that of the axis of the syncline.

The limestone has evidently been squeezed up by folding movements and has occupied the structural basin in which it lies, but the form of the land surface on which the limestone was laid down was not basin-shaped. There are similar basins in the country to the north-west, with parallel orientation, which do not now contain limestone outliers, but their form is so characteristic that their origin is probably similar to that of the Dove. These parallel elements may explain the north-easterly direction of the Hurunui in this part of its course, for after it leaves Maori Gully it apparently follows the line of these basins, with breaks across from one to another.

It may be noted also that the hills in this part of the valley rarely exceed 3,000 ft., but immediately to the north-west mountains rise to between 5,000 ft. and 6,000 ft., the marked difference in height being perhaps due to the fact that the lower area was faulted down along a line of settlement parallel to those occurring a short distance away in the Hanmer area and still farther away in the Kaikouras.

The indications certainly point to this submontane area having been covered with a veneer of sediments during Tertiary times; that it was raised with some faulting, and certainly with folding, in late Tertiary or in Quaternary times, the folding producing anticlines and synclines of the beds of limestone with a general north-easterly trend; and that these limestones were removed from the basins with the exception of that of the Dove. The drainage which now occurs may be called, as Cotton has suggested (1917, p. 253), "anteconsequent," in that it was perhaps consequent on the former land surface, but antecedent as far as the present surface is concerned. The determining factors of the original consequent drainage must in this case be highly speculative and almost impossible to determine.

(2.) *Hurunui-Waiau Basin.*

The salient features of the Hurunui-Waiau basin have been mentioned before by myself (1915, pp. 347–48). The formation of this mountain-ringed area is attributable primarily to faulting or folding movements, or a combination of both, for there is ample evidence that both are present. The Tertiaries on the north-west side of the basin lie on the basement beds of greywacke with a general dip to the south-east, but with occasional reversals where they abut against the older rocks. This is specially well seen near the road past Mount Mason into the Virginia country, where the limestones in close proximity to the greywackes experience a sharp fold

backwards as if the beds had been dragged down along a fault-line. Farther north towards the Hurunui Gorge, opposite their junction with the Mandamus, they appear quite normal, but in the Pahau again their structure is obscure, though that may be attributed to the disturbance in the immediate neighbourhood of a volcanic vent. Farther north-east towards Culverden their arrangement is again normal. The floor of the basin is almost completely masked by the gravels of the Hurunui and Pahau Rivers, the only indication of what is underneath being given in the vicinity of Hurunui Mound. Here the Tertiaries rise like an island in the sea of gravels, and they are evidently folded acutely. In the cliffs on the bank of the river near the railway-bridge the structure is anticlinal, but at the Mound itself, about half a mile to the north-east, the beds are also folded, though not on the same line. There is evidence, therefore, of a more complex structure under the plains—that is, they approach a synclinorium.

The southern margin of the plain from the road-bridge eastward is determined by a fault-scarp, along the foot of which the river flows. The settlement of the block of country under the plains appears to be more marked on the south-east side (*cf.* the Waikari and Greta Valleys, also the fault system of the Kaikouras: Cotton, 1914), and the river has therefore occupied it as the lowest level possible on the plains. The outlet, however, is marked by high-level terraces indicating a former higher level of the river. It is almost certain, therefore, that the deformational movements which caused the basin had not terminated when the river had established its course through the gap at the south-east corner of the plains. Of such recent movements the surrounding districts furnish ample evidence (*cf.* the fault-scarps near Hanmer, at Glen Wye, and also the recent gorge of the Middle Waipara). The course of the river from the junction of the Mandamus has followed the line of steepest descent to the fault-line, and is therefore approximately at right angles thereto. This explains the necessity of the sudden sharp turn when the line of the fault is reached. Although the high-level terraces at the outlet may be attributed to recent movements in the basin itself, they may be correlated with the uplift which all this region has recently experienced, and therefore are the result of the river accommodating itself to a new and lower base-level. The river-course across the plains is marked by terraces of no great height. It here follows a direction consequent on a surface of its own making, for which the term *auto-consequent* could be used. Thus the courses of the Rakaia, Rangitata, and other large rivers of Canterbury across the plains are auto-consequent.

(3.) *The Waikari-Kaiwara Basin.*

After leaving the Culverden Plain the river flows through a gorge cut in greywacke for about six miles till it enters on the Waikari-Kaiwara basin. This extends down the river to the immediate vicinity of the Ethelton railway-station, when the river passes through another gorge cut in greywacke. The basin is therefore completely enclosed by pre-Tertiary rocks. Although the area has a basin-shaped form, its origin is somewhat different from the Waiau-Hurunui intermontane area, and owes its formation entirely to the faulting-down of a strip of Tertiary beds and the subsequent enlargement of the tributary valleys through the rapid erosion of relatively weak beds. These consist chiefly of sands with harder concretionary bands, sandy clays, and marls, with occasional irregular layers of shells, mostly in a fragmentary condition: they are, in fact, the equivalents of the Motunau or Greta beds. Mount Brown beds are existent

as well, but I have found no appearance of limestone, which is so well developed in the Waikari district to the south-west. Limestone does occur in the upper part of the Scargill Valley, in the form of faulted strips, but I have not traced it farther towards the Hurunui. The beds have a general north-east strike, and a dip to the south-east of from 15° to 20°. Where the beds cut across the Hurunui, which they do at an angle of about 45°, they are disturbed from their proper dip and are pulled up along the line of a fault on the downthrow side till they are nearly vertical; but this disturbance does not extend far from the fault-line, and may be attributed entirely to the movements caused by it. The result is that the beds form a strip running along the north-west side of the Waikari-Kaiwara depression, with slope accordant to that of the underlying surface, and if they were removed a characteristic "stripped surface," as described by Thomson,* would be disclosed. I do not know what special name has been applied to valleys of this form, except that I think the term "basin range valley" has been applied to somewhat similar valleys in the western United States; but the Waikari Valley is of a somewhat different type, and also the name just cited is an unfortunate conjunction of terms. The name "rift valley" does not apply, because such are determined by faulting running along two sides, whereas these under consideration are attributable to tilting which has accompanied faulting along one line only. I suggest the name *tilted strip* as being a suitable name in case none has been already applied.

The most remarkable feature of the course of the Hurunui is its continuance across this depression without any apparent effect on its course. Although the earth-movements accompanying the faulting must have been of fairly recent date, the river has maintained its original course. It is interesting to compare this case with that of the Clarence Valley, farther north, where a similar valley caused by faulting on a much larger scale has dominated the course of the river. In the case of the Hurunui the movement must have been slow, and some cause must have been present which enabled the river to reach a lower base-level almost as fast as the downward movement occurred in the beds in this portion of its course. This cause will be evident from a consideration of the features of the next compartment into which the river-valley has been divided.

(4.) *The Greta-Cheviot Basin.*

The greywacke gorge of the river continues for about three miles below the Ethelton Station, when the valley opens out and the river has a wide shingly bed with flanking terraces cut in the marls of the Motunau or Greta series. Soon after its emergence from the gorge it receives the small Greta Creek, which occupies a valley similar in form and origin to that of the Waikari and Kaiwara. The beds let down by the fault which determines this valley develop northward into those of the true Cheviot basin, which is some five miles across, and extends past the Cheviot township across the Waiau as far as the Conway River. The structure of this basin is dominantly synclinal. The beds exposed on the floor of the basin are clays, sandy clays, sands, &c., of Mio-Pliocene age, passing down conformably into calcareous greensands (= Weka Pass stone) and hard limestone (= Amuri limestone). The limestone is exposed in places along the western edge of the greywacke ridge which separates the basin from the sea, and through which the Jed has cut its gorge. On the seaward side of this grey-

* J. A. Thomson, Coal Prospects of the Waimate District, South Canterbury, *N.Z. Geol. Survey, 8th Ann. Rep.*, p. 160, 1914.

wacke barrier the limestone also occurs, with reversed dip, and under the limestones are exposed sands and greensands with saurian bones, and thin beds of impure coal. On following the beds across the strike a synclinal arrangement is found, and the limestone forming the south-eastern limb appears as a reef at Port Robinson, striking out to sea just as the limestone reefs do at Amuri Bluff. This syncline is well seen in the cliffs at Gore Bay, and it no doubt extends south-west as far as the Hurunui, and appears where the rocks dip up-stream just above the lowest bridge across the river. The upturned beds of the south-easterly wing of this syncline rest at Port Robinson on greywackes, and at the Hurunui Bridge on the same rocks. In the last-mentioned locality there is evidence that the Tertiaries are bent over this core of greywacke in mild anticlinal arrangement. The river has cut a gorge through the greywacke, which has been used as a solid basis for the abutments of the bridge.

Up-stream from this, the traces of the anticlines and synclines which occur between Port Robinson and Cheviot can be seen occasionally where the Motunau beds are exposed in the river-terraces, but no limestone is visible; the general arrangement is, however, synclinal.

An important point as regards the history of the river is the comparatively recent elevation of the coast-line. This has amounted to as much as 600 ft., judging from the shore-platforms extending to that height at Port Robinson, between the mouths of the Hurunui and the Blyth Rivers (three miles to the south), and just south of the Blyth River on the summit of the Napenape Cliffs. This elevation has been noted previously by Haast, Hutton, and McKay. In the last-named locality there are sea-planed limestone surfaces 600 ft. above sea-level covered in places with marine gravels. In the country just south of the Hurunui this plain of marine denudation extends back from the present coast-line for some five miles to the base of the greywacke hills, and exhibits a peculiarity in that the wave-cut surface is higher near the coast than farther inland. This suggests that a slight warping has taken place since the plain was cut; but the peculiarity may perhaps be explained by the more ready erosion of the softer beds farther inland than the harder limestone exposed near the coast where it forms the floor of the high platforms. The first explanation is, however, the more reasonable, and if it is correct the axis of warping would approximate to that of the line of the greywacke bar near the river-mouth. Apart from the effect on the river in this vicinity, probably apparent in the gorge of the river incised in a somewhat wide flood-plain, an elevation of the land totalling some 600 ft. would exert considerable influence on a river which had reached approximate base-level, as it is reasonably certain that the Hurunui had, before the coastal elevation took place. The power of vertical corrasion would be greatly increased over a considerable part of the course of the river. At the present time a considerable portion of the Culverden Plains are under 600 ft. above the sea, and unless some compensations in level have taken place inside the coastal belt the level of the river-bed should have been greatly affected as far as the junction with the Mandamus at least, where the solid bars of rock would delay adjustment for a long period after it had taken place in the relatively weaker beds farther down-stream. There is, however, evidence of a lowering of the inland portion of the river-basin relative to the coastal portion as a result of the faulting which took place on the Greta line, on the Waikari-Kaiwara line, and again in the deformational movements of the Hurunui-Waiau basin. The effect of this would be to make this portion of the stream an aggrading one if the lowering were in excess of the coastal elevation. This has certainly been the case, for the aggregate throw of the faults must total

considerably over this. The effect of this has no doubt been to make the river an aggrading stream in that part of its course which lies in the Culverden Plain, and to neutralize the effect of the elevation perhaps as far down as Ethelton, but to rejuvenate the part between the Greta and the sea. Even this part is near a temporary base-level, judging by the great amount of shingle in its bed and the very low terraces of some parts of its course. This rejuvenation enabled the river to maintain its course in its lower portion across the grain of the country, to cut deep gorges through greywacke rocks, and to do this in spite of movements which would tend to turn it from its original course. As the present valley of the river is situated, there are several easier routes than that which it actually follows, such as that past Hawarden down the Waikari Valley, or past Hawarden into the valley of the Waipara and thus into the sea near Amberley. But it appears that under certain conditions, when the course of a river is once definitely established it will maintain that position in spite of influences which should divert it from its original path.

Development of the Course of the Hurunui River.

The geological features of this region which have primarily determined the course of the river are briefly stated as follows: On a greywacke surface, incompletely base-levelled, a series of beds was deposited chiefly in middle and late Tertiary times. These consist of sands sometimes with coal, greensands, limestones, marls, sandy shell-beds, and sandy marls passing up into conglomerates, the higher members being of Pliocene age. The general character of the strata indicates deposition on a sinking sea-bottom in the early part of the period, followed by deposition on a rising bottom at the end, the whole sequence being laid down without a physical break. It is probable that there was some differential elevation towards the close of the time, so that some of the earlier beds were eroded in places while continuous deposition was going on elsewhere. The sea in which deposition took place gradually extended over a wider area with the sinking of the land, since the higher members overlap the lower and cover a more extensive area. Thus it is that limestone is very thin or entirely absent in certain localities—for example, the Greta and Waikari Valleys—the land occupied by those localities being the last to be invaded by the sea during submergence, and having an entirely different form from that which it now has. No doubt a slightly elevated area occupied the site of those valleys in early Tertiary times.

The covering beds extended far to the eastward, but have been cut back by marine erosion, which is at present making marked inroads on the sea-cliffs composed of loose sands and marls; while to the westward the Tertiaries extended beyond the Mandamus River, probably to the vicinity of Maori Gully, but fragments of the greywackes rose like islands in the cover of more recent beds, though not in the position of the high lands existing at present.

On this surface of covering beds as it emerged from the sea a consequent drainage was established, consisting of subparallel streams running seaward in an easterly direction. Although it cannot be stated with certainty, it is probable that the first elevation of the land took place with comparatively little deformation, and the river-courses were well established before the dislocations became pronounced. After the rivers had been completely established, folding and faulting took place on lines cutting the direction of the main streams at an angle of approximately 45°, and these lines have determined the courses of the principal tributaries, most of which enter the main valley along fold and fault lines. The recency of the movements is

emphasized by the marked dependence of the landscape forms on the features resulting immediately from these movements. In some cases time has not been sufficient for the weak covering beds to be removed from the higher elevations, though in general these are more perfectly preserved in the folded and faulted intermonts. The movements producing these must have been slow, although they have been comparatively recent, since the main stream has preserved its original direction with but slight modifications, in spite of the opportunities presented for departing from it as a result of these movements, while farther north in the Kaikoura region the movements were on such a scale that the stream-systems are almost entirely dependent on them for their direction. The Hurunui region thus illustrates the condition that a powerful stream may at times maintain its original direction in spite of strong forces tending to deflect it. Dr. Cotton has drawn my attention to a paragraph in a paper by Professor W. M. Davis, entitled "An Excursion in Bosnia, Hercegovina, and Dalmatia," * which seems appropriate in this connection. It reads as follows: "It is evident that this hypothesis [warping] accounts simply enough for the occurrence of irregularly alternating basins and uplands; and that the basins thus produced might be connected by gorges eroded through the uplands by the master rivers; the gorges marking either the paths of antecedent streams that had maintained their course in spite of the warping, or paths selected by the drainage consequent on some early stage of warping and antecedent to the rest." This idea of anteconsequent streams has been elaborated by Cotton (1917, p. 253), and it seems entirely applicable to the case of the Hurunui, except that faulting has ensued as a result of the strains set up in the warping movements.

GLACIAL FEATURES OF THE HURUNUI VALLEY.

(See map, fig. 2.)

Although there are no present-day glaciers in the valley of the Hurunui, the mountains not being sufficiently high in that part of the alpine region to intercept sufficient snow to feed them, the upper part of its basin was subjected to the severe glaciation which affected a large part of the South Island of New Zealand in Pleistocene times and perhaps later. Haast has indicated (1879, plate 11) that the Hurunui Glacier at its greatest extension came down below the junction of the Waitohi River with the main stream—that is, well on to the Culverden Plains; but on what evidence he bases this great extension is not clear, and in my opinion there is no reason to demand it. The absence of morainic and other glacial deposits, as well as the form of the river-valleys in the middle course of the Hurunui, render his supposition very improbable. Especially is the latter evidence strong in the case of Maori Gully, the striking gorge which the river has cut in the edge of the high-mountain country before it runs through the foothills of the Alps. This is so deep and narrow that it is almost impossible that ice could have come through it and left it in its present condition. It seems to me extremely probable that the ice did not extend below the junction of the two main branches of the river, if indeed it came so far, since there is no proof of its former presence even at this point except the somewhat indefinite evidence based on the form of the river-valley, which may be attributable to ice action or may be the result of ordinary stream erosion. In the absence of other proof this solitary line of evidence must be viewed with considerable reserve.

* *Bull. Geog. Soc. Philadelphia,* vol. 3, No. 2, pp. 21–50, 1901.

Above the junction of the two branches the evidence is undoubted, especially from the vicinity of the Lakes Station and Lake Sumner towards the head of the river. Old moraines, smoothed and rounded surfaces, and the form of the cross-section of the valleys furnish indubitable evidence of the former presence of ice. In the upper part of the course of the North Branch the even alignment of the valley-walls, their steep lower slopes and gentler upper ones, the truncated and semitruncated spurs, and the *roches moutonnées* on the valley-floor are as characteristic of the results of glaciation as anything in the valleys of the Southern Alps farther south. On the north side of the river the mountain-tops have a very flat plateau-like form, and this feature continues as far as the valley of the Waiau, if

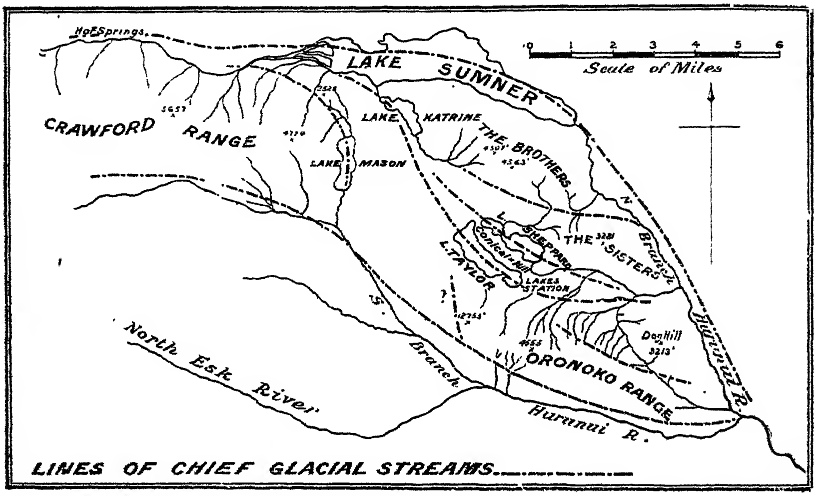

FIG. 2.—Upper Hurunui Valley.

not farther, so that the streams run in deep trenches incised in the table-land. To the south of the river the mountain-tops are more like those characteristic of middle and southern Canterbury, with rugged summits and wide expanses of moving debris dislodged from solid rocks by the action of frost. To the east of the plateau region the mountains take on this form even to the north of the river.

Specially interesting features of the river-basin have resulted from the action of these ancient glaciers on a mature valley-system which had become established in pre-glacial times. These features are so strongly reminiscent of those of the valleys farther south, especially of the Waimakariri, that they must be attributable to a common cause. The only difference in the two cases is that the features of the Hurunui are not so strongly marked, which is no doubt due to the more moderate intensity of the glaciation in the northern river. Thus there are distinct traces of the original directions of the streams, which are wanting farther south, but which may give some clue to the origin of the characteristic features of the valleys.

Parallel Valley System of Upper Part of Basin.

The most striking landscape form of the upper basin of the Hurunui is the series of subparallel valleys flanking the North Branch on its southern side. These are quite analogous to those of the Waimakariri, also on its southern side, and to those in the vicinity of Lake Coleridge in the valley

of the Rakaia. The arrangement is as follows, taking the valleys in their turn, commencing from the north:—

(1.) *The main valley of the North Branch leading into Lake Sumner.* This has a general east-and-west trend, with wall-like sides in good alignment, but broken by tributary valleys, especially on its northern side. Lake Sumner occupies a continuation of this valley, but about half-way along the lake the trend assumes a north-west and south-east direction more in agreement with that of the others. This corresponds in direction and salient features with the main valley of the Waimakariri, but the landscape characters are on a smaller scale.

(2.) *The set of subparallel valleys leading from the vicinity of the head of Lake Sumner, near Lake Katrine, and running south-east.* At the head of the system there is only one main valley, but it breaks up within a short distance into distributaries consisting of—(i) A valley immediately to the south of Lake Sumner and divided therefrom by a ridge of which the peaks known as The Brothers (4,563 ft. and 4,507 ft.) are the highest points; (ii) a valley in which lies Lake Sheppard, divided from (i) by a discontinuous ridge ending in The Sisters (3,281 ft.); (iii) a valley in which lies Lake Taylor, divided from the former by Conical Hill (2,783 ft.) and from the valley of the South Branch by the Oronoko Range. These valleys are quite analogous to those in the Waimakariri basin, which may be called (i) the Lake Blackwater Valley, (ii) the Lake Sarah - Sloven's Creek Valley, and (iii) the Lake Grassmere - Lake Pearson - Winding Creek Valley. They also resemble the still more remarkable and perfect system to the east of the Rakaia basin in the vicinity of Lake Coleridge.

The ridges which divide these valleys are analogous in their physical characters. They are very steep-sided, with somewhat narrowed cross-section, so that when viewed end-on they appear conical; hence the frequent occurrence of such names as "Sugarloaf" and "Conical Hill" in North Canterbury. But when viewed from the side they form long ridges cut into well-defined saddles (*cf.* Mitre Peak). When this saddle is low and little elevated above the floor of the valley in the vicinity the ridges become isolated hills, which are often in pairs or linear series, and give rise to such names as "The Brothers" or "The Sisters."

The valleys indicated above junction with the main valley of the North Branch after it leaves Lake Sumner and takes the first decided bend of the river to the south-east. It soon afterwards receives the South Branch. In its upper part this valley has an east–west direction, but it soon takes on the characteristic north-west and south-east orientation, and finally turns and joins the other branch nearly at right angles. The dividing wall between it and the Lake Taylor Valley to the north, called the Oronoko Range, has been partially broken down in several places. The most important of these lies just opposite the head of Lake Sumner, where a low pass leads from the northern to the southern valley of the Hurunui. On the southern side of the pass is Lake Mason, tucked away in a tributary valley of the South Branch. The country in this neighbourhood has been highly glaciated, *roches moutonnées* and smoothed surfaces forming characteristic features of the landscape. Opposite the Lakes Station there is another saddle—somewhat high, it is true—and the ridge has also been lowered in a line with the Lake Taylor Valley leading directly to the North Branch south of Dog Hill, indicating an overflow in that direction.

The partial dismemberment of this ridge affords a clue to the conditions which obtained before dissection and isolation overtook the ridges to the north-east. By noting its features it is possible to restore with reasonable

certainty the general direction of the streams that flowed through this tract of country anterior to the glaciation. In addition to the two main branches of the river a large stream rising near the head of Lake Sumner followed the course of the Lake Taylor Valley, parallel with the South Branch; this entered the North Branch about half-way between Lake Sumner and the junction of the two main branches. A small tributary entered this valley on the north side, rising near the head of Lake Taylor and following the course of Lake Sheppard. Another small stream rose near Lake Katrine and joined the North Branch below the outlet of Lake Sumner. In pre-glacial times the ridges dividing these valleys would be more or less entire, though they might have saddles at their heads. It is impossible to reconstruct such features exactly, but the description just given affords a fairly accurate view of the stream conditions which obtained in this tract of country before it was modified by glaciation.

Whatever was the prime cause which promoted glacier extension, it is reasonable to assume that it was gradual in its incidence. Snow would slowly accumulate, glaciers would be formed at higher altitudes and slowly extend down the valleys. Thus the heads of the small valleys would probably be filled with corrie glaciers, while the glaciers of the first order would be extending down the main valleys. These would help to lower the divides in the way suggested by Matthes.* As the ice-flow increased in volume the main streams would be filled, and in time overflows would take place over the lowest part of the divides, which would be lowered at the same time by active ice abrasion. It is significant that the greatest amount of lowering has taken place near the head of Lake Sumner. This would be due to the marked overflow of ice from the main Hurunui Valley, no doubt due to the narrowing of the cross-section of the valley at Lake Sumner, which caused the ice to overcrowd into the headwaters of the neighbouring streams, as it has done in several of the valleys of the Canterbury rivers. The full force of this would be felt at the head of the Lake Taylor Valley, and thus its divide has been completely reduced. The headwaters of the intermediate tributary valleys were also invaded and the saddles at their heads reduced. Thus a clear passage for the ice was opened down these valleys past the site of the Lakes Station in the direction of the south-easterly reach of the North Branch below Lake Sumner, while the main stream of ice followed down the valley now occupied by this lake.

In addition to the overflow toward Lake Taylor, a powerful stream passed over into the tributary which runs into the South Branch from the north. The saddle at the head of this stream was thus reduced, but not so much as its neighbour, which was more in the line where the ice-stream would impinge on the valley-wall. If, however, glacier action had continued this saddle would have been reduced and the mountain ridge to the north of the South Branch would have been completely isolated. It is possible that ice also overflowed into the valley of this stream near the Lakes Station, and as at the height of the glaciation the country in its vicinity would have the form of an intermontane basin, and would be an efficient gathering-ground, overflows from it took place along several lines from the front of the ice-sheet in the direction of the valley of the North Branch. These would produce the breaks in the valley-wall between the South Branch and the country to the north which occur immediately up-stream from the junction of the two branches.

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* F. E. Matthes, Glaciation of the Big Horn Mountains, *U.S. Geol. Surv. 21st Ann. Rep.*, 1899–1900.

The dismemberment of the ridges would no doubt be promoted by the sapping-back of the valley-walls and their complete reduction in places where the ice-stream impinged more powerfully. If we compare the results of the glaciation in other valleys we see that in their cases the dismemberment has been more complete, the dissection of the dividing ridges carried to a further stage, and the straightening of their sides more thoroughly carried out, because they experienced more complete glaciation. If we were furnished in these cases with more clear indication of the intermediate condition of the direction of drainage it would be possible to reconstruct the original stream-system.

There is one point, however, which has not been considered fully—viz., the agreement in the direction of the tributary valleys with those of the Waimakariri and Rakaia. Is this agreement in orientation the result of accident, or is it based on some structural condition which has influenced the country in the basin of the Hurunui as well as the country farther south ?

I have shown (1916, pp. 142–43) that there exists in the mountain region of Canterbury a well-marked series of fractures or lines of folding which lie in a north-west and south-east direction. Cotton (1917, p. 273) draws special attention to the importance of the north-west system of earth-fractures in Otago as compared with the other parts of this Island, but they certainly occur in Canterbury in conjunction with the Kaikoura system, and it is possible that in the upper Hurunui, as in the Waimakariri, they are co-existent. Since writing the article referred to above I have noted additional lines with the north-west orientation, especially in the upper valley of the Waipara and in South Canterbury in the country between Fairlie and Cave. In both these cases there are undoubted, well-marked lines of fault. It is possible, therefore, that the general direction of the valleys at the head of the Hurunui were determined initially by lines of structural weakness. It is remarkable also that some of the valleys on the northern side of the river have a characteristic east-north-east orientation, and these are parallel to other valleys farther north, such as the Hope, in the basin of the Waiau. On the line of one of these upper valleys is the hot spring which forms a noteworthy physical feature of the Upper Hurunui, and I am informed that other springs occur in the valley which stretches north-east from this locality. This certainly points to the presence of an earth-fracture with east-north-east orientation.

Another feature of this district should be noted—viz., the north-and-south trend of the upper valleys of the Waiau and Clarence, a direction which is parallel to the twin valleys of the Mandamus, and to that of the Glenrae, lying to the west of these. The arrangement may be only a coincidence, but it is certainly a striking one.

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Art. VII.—*The Volcanic Rocks of Oamaru, with Special Reference to their Position in the Stratigraphical Series.*

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Contents.

I. Introduction.

Interpretations of the geology of the Oamaru coastal district where the typical Oamaru series is developed have varied greatly in the past, and, although there is now pretty general agreement as to the broad features of the rock-sequence, it is essential that more detailed stratigraphical work should be attempted if the best results are to be obtained from the determinations of the Tertiary fossil Mollusca and Brachiopoda, which are being carried out by Mr. H. Suter and Dr. J. Allan Thomson. Many of these fossils have been collected from the Oamaru district, the exact locality and rock from which they have been gathered are known, and, if the stratigraphical sequence can be determined in greater detail than has been done in the past, correlation of Tertiary rocks in other parts of the Dominion with those developed in the typical locality will possess a sounder basis than it does at present.

Misinterpretations of the rock-sequence at Oamaru have undoubtedly been caused by faulty identification of the horizons of the volcanic rocks, and it will assist stratigraphical work if these can be determined more accurately.

The position of the lowest volcanic rocks, the Waiarekan, is not in question; it is generally agreed that they lie immediately below the Ototara limestone, and my work in the North Otago district has convinced me that they are invariably associated with deposits of diatomaceous earth in the Oamaru and Papakaio areas. Difference of opinion has, however, been sharply marked when dealing with the volcanic rocks near the Oamaru coast. These have been correlated with the tuffs in the Waiareka area; important unconformities have been introduced into the sequence, on the ground that the volcanic rocks are clear evidence of the existence of a former land surface. An attempt will be made in the present paper to define more clearly the place of the volcanic episodes in the late geological history of the Oamaru district. In 1916 I gave a detailed sequence of the rocks east of the Waiareka Valley, and some of the evidence on which the succession was based was presented in that paper. It is now proposed to bring additional evidence by describing several sections in the neighbourhood

of the town of Oamaru. The pillow-lavas that occur in some localities will be described, and a preliminary reference will be made to the microscopic characters of some of the rocks, a detailed description of which must be reserved for a future paper. I am much indebted to Dr. Thomson and Mr. H. Suter for naming many of the fossils. Their determinations are indicated by an asterisk placed in front of the name of the fossil. The other determinations have been made by myself by comparison with forms determined by these palaeontologists.

II. THE SUCCESSION OF THE ROCKS OF THE OAMARU SERIES.

It will be advisable at the outset to state briefly the detailed succession of the Oamaru series as developed in the typical locality. The classification of the upper rocks is based mainly on evidence to be brought forward in this paper.

To the west of Oamaru, in the basin of the Kakanui River, the lowest Tertiary rocks are the grits, clays, and sandstones, sometimes associated with lignite deposits, the whole forming the Ngaparan stage. These are followed by a considerable thickness of greensands, and these in turn are succeeded by a great thickness of breccias and tuffs, occurring in the Waiareka Valley. Towards the top these become fine-grained and tachylytic, and are interbedded with deposits of diatomaceous earth, which, in addition to the vegetable micro-organisms, contains an equal abundance of sponge-remains and Radiolaria. Dykes and sills have intruded the tuffs and diatomaceous earth, and the siliceous rock has in many places been completely metamorphosed into a flinty substance. These constitute the Waiarekan stage. The Ototara limestone is the next succeeding rock. In its lower portions it is interstratified with thin beds of marl, and occasional thin layers of rolled volcanic pebbles. In its middle portion it is in some localities intercalated with tufaceous bands, but these are probably detrital only. In other localities the deposition of the limestone continued uninterruptedly; and it is free from volcanic material. Towards the end of the limestone period volcanic activity was renewed in localities near the present coastline with the eruption of the breccia at Kakanui and the volcanic rocks in the neighbourhood of Oamaru, the upper pillow-lava of the latter locality being younger than the breccia. After volcanic action had ceased limestone continued to be deposited, but in many places it contains large well-rounded masses of volcanic rocks, and minerals similar to those occurring in the breccia below. It is more than probable that the Kakanui breccia formed small islands or submarine banks, for it is followed by limestone bands and tuffs, the former containing rolled fragments of the breccia. In Oamaru Creek these interstratified tuffs and calcareous bands are invaded by a thick mass of dolerite which has overflowed to the north and formed the upper pillow-lava near Grant's Creek. This in its turn is followed by the limestone containing the large volcanic boulders. The latter disappear towards the top of the limestone, which closes the Ototaran stage. The greensands of the Hutchinsonian stage followed the limestone, and the sequence closed with the mudstones of the Awamoan stage.

III. PREVIOUS OPINION IN REGARD TO THE HORIZON OF THE VOLCANIC ROCKS.

Hector (1865) considered that the volcanic rocks near Hutchinson Quarry, in the town of Oamaru, were submarine, but he based his conclusion on the

erroneous assumption that the hard limestone bands in that locality had been metamorphosed during deposition by a lava-flow.

Hutton (1875, p. 54) said, "No eruptive rocks are found associated with the older or Ototara group of strata . . . . but at Oamaru Heads we have clear evidence that during the deposition of the Upper or Trelissic group of beds volcanic action was going on."

In 1876 McKay placed the Waiareka tuffs below the Ototara stone, and asserted that a younger series of volcanic rocks occurred at Oamaru.

In 1886 Hutton verified McKay's observations as to the position of the Waiareka tuffs, but repudiated his own former statement that volcanic rocks were associated with the upper beds of the series. He recognized but one horizon of volcanic rocks, the Waiarekan, and considered that the volcanic matter in the upper part of the limestone was detrital only.

In 1905 Park asserted that volcanic activity commenced at the end of the Waihao greensand period and culminated during the deposition of the Hutchinson Quarry beds.

Summarily, according to McKay there were two distinct periods of eruption, the pre-Ototaran and the pre-Hutchinsonian; according to Hutton but one, the pre-Ototaran; while according to Park activity continued during the Waiarekan, Ototaran, and Hutchinsonian periods.

IV. Effects of these Opinions on the Classification of the Oamaru Series.

The fact that the volcanic rocks are always followed by limestone has undoubtedly caused confusion in classification, and in the absence of distinctive fossils in the limestone the igneous rocks near the coast have been assumed to be Waiarekan. McKay, although recognizing the Tertiary volcanics at Oamaru as distinct from his Cretaceo-Tertiary Waiarekan tuffs, erroneously supposed the breccias at Kakanui to be Waiarekan (1877, p. 56), whereas they are middle Ototaran. Hutton in ascribing the volcanic rocks at Oamaru to the Waiarekan was necessarily compelled to introduce an unconformity above them to account for the non-existence of the Ototara stone. Park's contention that volcanic activity culminated during the Hutchinson Quarry period may be true or not true; it depends entirely on the connotation of the term "Hutchinson Quarry beds." McKay seems to have been the first geologist to use the term in classification (1882, p. 58). Later in the same report (p. 76) he seems to restrict the term to the greensands alone, correlating the calcareous beds with the Otekaika limestone, and the volcanic rocks below with the *Kekenodon* beds. In other words, in the typical locality he excludes the limestone bands. This is in substantial agreement with Thomson's use of the term "Hutchinsonian" (1916, p. 34).

Hutton was probably correct in considering much of the volcanic matter detrital only, as will be demonstrated in the sequel. Further, McKay considered the volcanic rocks of Oamaru Creek as evidence of a land surface, and he supposed the overlying rocks to be markedly unconformable to them (1877, p. 58). My own opinion, based on the evidence furnished below and on further observations in other parts of the Oamaru district, is that deposition was continuous from the base of the Ototaran to the top of the Awamoan, but interrupted locally by submarine eruptions resulting in the formation of volcanic banks or islands, which, however, suffered rapid denudation, and this minor phase is recorded in the slight unconformities now to be seen in the tufaceous beds.

V. DESCRIPTIONS OF THE SECTIONS.

(1.) *Oamaru Lighthouse.*

In the sea-cliff below the lighthouse near the Oamaru Breakwater a good section is exposed (see fig. 1).

The tufaceous beds (*a*) are interstratified with limestone bands, which often contain large subangular pieces of vesicular basalt. The bands themselves vary up to 1 ft. in thickness, the lowest being 170 ft. below the base of the lower pillow-lava. There is a marked discordance in the dip of the tufaceous rocks below (*a*). These are not shown in the figure. They dip 40° N. by E., while the dip of (*a*) is only 20° N. by E. It is probably at this point that McKay introduces his unconformity between his Cretaceo-Tertiary and Upper Eocene beds (1877, p. 58). From the calcareous bands in the tuffs I collected the following forms: **Emarginula wannonensis* Harris, *Siphonalia* sp., *Dentalium solidum* Hutt., **Pecten hutchinsoni* Hutt., *Siphonium planatum* Suter, *Liothyrella oamarutica* (Boehm), *L. boehmi* Thomson, *Terebratulina suessi* (Hutt.), *Aetheia gualteri* (Morris), and *Hemithyris* sp.

The overlying pillow-lava is at a minimum estimate 100 ft. thick. The interspaces are filled with fossiliferous limestone, much hardened in places by a secondary deposit of calcite, and the fossils are difficult to extract A detailed description of this peculiar rock and others similar to it will be given later. The following fossils were obtained from the interstitial limestone: **Trochus* sp., **Turritella* sp., **Polinices huttoni* von Ihering, **Lima bullata* Born, **Lima lima* (L.), *Ostrea* sp., and *Hemithyris* sp.

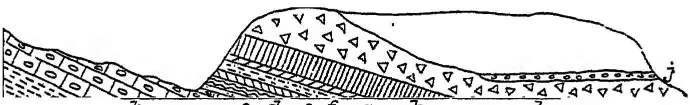

FIG. 1.—Section near lighthouse, Oamaru. (*a*) Tuffs with limestone bands; (*b*) lower pillow-lava; (*c*) fine tuffs (current-bedded); (*d*) tuff-bed (very calcareous); (*e*) limestone band with rounded and subangular pieces of volcanic rock; (*f*) blue tufaceous clay; (*g*) limestone; (*h*) tufaceous limestone; (*j*) raised beach; (*k*) broken pillow-lava.

The tuff-beds (*c*) are very fine and current-bedded, but unfossiliferous. The overlying tuffs (*d*) are very calcareous and coarser in texture. I collected the following forms: *Epitonium lyratum* (Zitt.), *Lima jeffreysiana* Tate, *Ostrea* sp., *Venericardia purpurata* (Desh.), and *Diplodonta zelandica* Gray.

The limestone band (*e*) is crowded with subangular pieces of volcanic rocks, while small pieces of augite were also identified. Bed (*g*) is a much purer limestone than bed (*h*), which is very tufaceous.

In the limestone (*g*) the following forms occurred: *Epitonium lyratum* (Zitt.), **Pecten hutchinsoni* Hutt., **P. delicatulus* Hutt., *Terebratulina suessi* (Hutt.), **Liothyrella boehmi* Thomson (?), and **L. oamarutica* Boehm.

The overlying tufaceous limestone (*h*) is also fossiliferous, and the following species were identified: **Limopsis aurita* Brocchi, *Pecten delicatulus* Hutt., **Lima jeffreysiana* Tate, *Ostrea* sp., **Venericardia purpurata* (Desh.), *V. zelandica* (Desh.), *Protocardia pulchella* (Gray), and *Terebratulina suessi* (Hutt.).

This bed passes insensibly into a completely tufaceous bed with occasional pillows scattered through it. The tufaceous matter, however, rapidly diminishes, and the rock becomes a pillow-lava, which will be discussed in the sequel.

(2.) *Oamaru Rifle Butts.*

Near the Oamaru Rifle Butts, on the south-west side of Oamaru Cape, a clear section is exposed on the beach. It is interesting, as the pillow-lavas are absent and a bed of limestone nearly 50 ft. thick is followed almost immediately by the Hutchinsonian greensands. A fault occurs immediately north of this section, and just beyond the fault there is a marked stratigraphical break in the tuff-beds, exactly similar to the unconformity described in the tuffs near the breakwater.

The section extends from a point immediately north of the target sheds to the fault which cuts the tuffs just past the first headland.

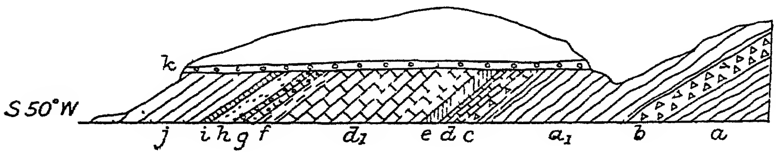

FIG. 2.—Section northwards from Rifle Butts, distance about 160 yards. (*a*) and (a_1) tuffs; (*b*) calcareous fossiliferous tuffs, 1 ft.; (*c*) limestone agglomerate, 2½ ft.; (*d*) (7 ft.) and (d_1) (40 ft.) limestone; (*e*) fine blue tuffs, 8 ft.; (*f*) greenish calcareous tuffs, 11 ft.; (*g*) indurated nodular limestone, 4 ft. 4 in.; (*h*) brachiopod greensand; (*i*) shell-bed, 2 ft.; (*j*) blue clay 100 ft.; (*k*) raised beach.

The tuffs (*a*) and (a_1) are calcareous throughout. From the band (*b*) I collected the following forms: *Turbo* sp., *Turritella* sp., *Siphonalia conoidea* Zitt., *Venericardia purpurata* (Desh.), *Diplodonta zelandica* Gray, *Chione mesodesma* Reeve (?), *Dosinia caerulea* Reeve, *Mesodesma subtriangulatum* (Gray), *Siphonium planatum* Suter, and *Liothyrella oamarutica* (Boehm).

Band (*c*) is a limestone crowded with subangular pieces of volcanic rock, with occasionally inclusions of a coarsely holocrystalline basic igneous rock. Masses of tuff, broken minerals, and pieces of rounded vesicular basalt occur, one of those being 1 ft. in diameter. The bed (*e*) is a fine brownish tuff weathering blue, and containing several limestone bands. I obtained the following fossils from one of these bands: **Pyrula* sp., **Lima lima* (L.), **Pecten* sp., and *Penacrinus* sp.

Mr. Henry Suter writes in regard to the genus *Pyrula*, "It is an unexpected addition to our fauna, and indicates a much warmer sea, the genus living now only in tropical latitudes. It is not found Recent in Australasia, but a species was described in 1888 by Pritchard from the Eocene of Table Cape, Tasmania."

The thicker bed of limestone (*d*) resembles the building-stone of the Oamaru district; it is poor in Mollusca and Brachiopoda, but I collected the following: *Siphonium planatum* Suter, **Pecten hutchinsoni* Hutt., *Aethcia gualteri* (Morris), and *Hemithyris* sp.

Overlying the limestone is a fine light-greenish calcareous tufaceous mud, which is very fossiliferous. The species identified were: **Siphonalia conoidea* (Zitt.), **Limopsis zitteli* von Ihering, **Pecten delicatulus* Hutt., **Lima angulata* Sow., **L. bullata* Born, **L. colorata* Hutt., **Venericardia purpurata* (Desh.), and **Mesodesma australe* (Gmel.).

The nodular limestone is of a similar character to the concretionary bands described by the present writer at Kakanui (1916, p. 23), but in the present occurrence there is very little glauconitic sandy material present, and the band is extremely hard throughout, the nodules being set in a calcareous matrix. The nodules vary in size up to the size of a cricket-ball; they show a concentric structure, with occasionally a central nucleus, while sometimes the centre is hollow.

The brachiopod band is a calcareous glauconitic sand, crowded with the typical Hutchinsonian fossil *Pachymagas parki* (Hutt.). Other species that occur are *Pecten delicatulus* Hutt. and *Pecten* (*Pseudamusium*) *huttoni* Park.

The shell-bed (*i*) is 2 ft. thick, and consists of a mass of shells embedded in fine grey sands. The fossils are much broken and very friable, and it was difficult to obtain specimens. The bed, however, is similar to the shell-beds at Target Gully and Ardgowan described by Marshall and myself (1913). One fossil obtained here was *Aetheia gualteri* (Morris), which has not hitherto been obtained above the characteristic *Pachymagas parki* greensands. Overlying the shell-bed is a blue mudstone with well-preserved fossils which clearly indicate that the bed is Awamoan. A list of fossils from this rock has been given by Marshall (1915, p. 384).

The two sections described above are exposed on the extreme north and extreme south respectively of a main anticlinal fold, the arch of which has been thrown into minor undulations and faulted in several places. Between the two exposures tuffs are exposed everywhere along the foreshore, but they have not yet proved fossiliferous. Although, as mentioned above, there are stratigraphical breaks in these tuffs and breccias, they are apparently of minor significance, as the rocks above and below are lithologically similar. Former observers have considered this underlying mass of volcanic rocks to be Waiarekan, but there is not the slightest positive evidence to support this contention. If they are Waiarekan, the breaks in the sequence mentioned above assume a much greater importance, for they will represent the time during which the greater part of the Ototara stone was being deposited.

(3.) *Hutchinson Quarry and Neighbourhood.*

Near the abandoned quarry at Eden Street the typical Hutchinson Quarry beds occur. Although the exposures in this locality are small and disconnected, the succession is clear, and will be best represented by a diagrammatic vertical section.

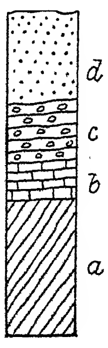

FIG. 3—Section at Hutchinson Quarry. (*a*) Tufaceous rock, 20 ft.; (*b*) limestone bands with tufaceous rock, 6 ft.; (*c*) limestone conglomerate, 11 ft.; (*d*) greensand, 15+ ft.

The lowest beds are fine calcareous tufaceous rocks (*a*) weathering greenish-brown, containing in places large fragments of decomposed vesicular basalt, and ramified throughout by calcareous veins. The bed is 20 ft. thick in the section, but the base is not visible. This passes gradually into the overlying bed (*b*), which is 6 ft. in thickness. It is a confused mass of glauconitic sands, hardened limestone, and tufaceous matter. In places, however, the limestone shows in bands from 1 in. to 1 ft. in thickness. Fragments of fossils are visible but none are recognizable. Overlying is a mass

of limestone (*c*) thickly crowded with decomposed rolled volcanic rocks up to 1 ft. in diameter, while the limestone itself contains small fragments of augite and olivine. The junction of this bed with the underlying tufaceous bed is unconformable in the section, but is probably due to contemporaneous erosion. Towards the top the limestone is free from the conspicuous volcanic boulders, and becomes very hard. This limestone has been proved phosphatic. It is overlain by glauconitic greensand—the typical Hutchinson Quarry greensand—crowded with brachiopods belonging chiefly to the two species **Pachymagas parki* (Hutt.) and **Rhizothyris rhizoida* (Hutt.).

As the gully is followed towards the Oamaru reservoir, outcrops are conspicuous on the hillside, but the sequence is similar to that just described. Past the farmhouse, however, the underlying massive volcanic rock crops out, and this proves to be the same rock that occurs at Chelmers Street quarry as a thick dyke which has overflowed to the north, and developed pillow structure in the bed of Oamaru Creek near Grant's Creek. At the latter locality it clearly underlies a limestone "conglomerate" and limestone capped by the greensands, exactly as at Hutchinson Quarry. The section at Grant's Stream is described in another paper in this volume (p. 121). The brecciated pillow-lava is undoubtedly the same as the upper pillow-lava that occurs above the fossiliferous beds near Oamaru Breakwater (see p. 109). Park, McKay, and Hutton, in discussing the section at Oamaru Breakwater, referred these fossiliferous beds to the Hutchinson Quarry horizon; but whatever interpretation is given to this term, these beds at the breakwater are certainly below the volcanic rock which, at Hutchinson Quarry and the locality near Grant's Creek, is overlain in ascending order by tufaceous beds, from 10 ft. to 20 ft. of limestone, and the typical Hutchinson Quarry greensand.

The well-rounded appearance of the volcanic boulders in the limestone in the neighbourhood of Oamaru Creek, and the confused intermingling of limestone, greensand, and rolled igneous rocks above the brecciated pillow-lava furnish evidence of denudation of the underlying volcanic rocks, which had formed small islands in the Tertiary sea. Formation of islands by submarine eruption is not an uncommon occurrence even in quite recent times, and has been noted by competent observers, who have always recorded the rapidity of their disappearance. This is probably the explanation of the various stratigraphical breaks that have been already referred to.

Lister (1891, pp. 596–606), in a paper on the geology of the Tonga Islands, arranges the islands in three main divisions—(*a*) purely volcanic islands; (*b*) islands formed of volcanic materials laid out beneath the sea, since elevated, with or without a covering of reef-limestones; (*c*) islands formed entirely of reef-limestone. Some of the islands of class (*b*) exhibit suggestive resemblances to the upper Ototaran rocks. These resemblances may be summarized under the following heads:—

(1.) They are built up of layers of tuff capped by calcareous rocks;

(2.) The fragments of some of the breccias are cemented by a calcareous matrix;

(3.) Rounded boulders of volcanic rocks occur in layers embedded in a calcareous matrix;

(4.) Some of the tuffs are penetrated by volcanic dykes which do not penetrate the overlying limestone;

(5.) Fragments of basic plutonic rock occur on one of the islands;

(6.) Some of the limestones are not true coral-reef limestones, but, according to Sir John Murray, are "chiefly made up of calcareous organisms, fragments of molluscs, echinoderms, Polyzoa, and calcareous algae, together with a large number of Foraminifera."

The plutonic rock mentioned above is a gabbro. Garnet also occurs, as it does in the Oamaru rocks. The intrusive rocks, however, are augite and hypersthene andesites.

In view of Mr. Suter's remarks in regard to the genus *Pyrula*, mentioned above, it is interesting to find that this genus occurs as a fossil in the tufaceous rocks of the island of Mango, one of the Tonga Islands.

VI. THE PILLOW-LAVAS.

Park (1905, p. 513) was the first geologist to recognize the lower rock near the breakwater as a pillow-lava. Since then the present writer has discovered the same peculiar rock in other localities of the district—in the basin of Oamaru Creek, and in the Awamoa Creek near Deborah. At the breakwater, also, the upper so-called "tachylyte breccia" is undoubtedly a pillow-lava which in parts has become brecciated, probably through local explosive action when coming into contact with the sea-water.

The lower pillow-lava (see fig. 1) consists mainly of spheroidal masses of lava with the interspaces filled with fossiliferous limestone. The junction with the tuffs below is quite even, and the surface of the tuffs shows no irregularity or indication of having been baked. The dip of these beds is N. 20° E. at an angle of 16°, and the tuff-beds overlying the lava have a similar dip. Each pillow has a tachylytic selvage about 1 in. in thickness, but the rock is holocrystalline at the centre. The pillows at the base of the flow are somewhat irregular in shape, but higher in the mass they become more spheroidal. One of the pillows near the base has a diameter of 30 ft. Higher in the section they are smaller, decreasing in diameter to about 2 ft., but towards the surface they again increase in size. Some of the pillows are much elongated; sometimes they show an indented periphery; occasionally the indentation has penetrated to the centre of the mass, and the upper half appears as if it had fallen over toward the lower half while still in a viscid state. Vesicles are by no means prominent in the rock. Occasionally large scattered ones occur, but on the tachylytic margin they are small and rounded. At the bottom of the flow the vesicles are small, and occur chiefly towards the exterior of the spheroid. Near the top of the lava the pillows are almost free from vesicles. By infiltration of calcareous solutions the rock in places becomes amygdaloidal. The fossiliferous limestone which separates the pillows is indurated, but there is no indication of alteration by heat.

The broken-up pillow-lava, which is separated from the rock just described by a thickness of 50 ft. of calcareous tuffs and interstratified limestone, has always been referred to as an agglomerate or breccia; but it is clearly a pillow-lava that has been locally broken up during flow.

The pillows vary much: some are similar to those already described, others are much elongated and almost scoriaceous, the vesicles being abundant and much drawn out. The rock throughout is much more vesicular than the lower lava. One pillow was noticed in which a large central cavity was coated with tachylyte, as well as the periphery. There is great variation in the size of the masses, the smallest having a diameter

of 6 in., while the largest are as much as 10 ft. across. The material that separates the pillows consists of fragments of pillows that have become broken up; some of the pieces are tachylyte, others have a selvage of tachylyte, while others are free from tachylyte; and this interstitial material is cemented by crystalline calcite. Only in one place does fossiliferous limestone fill the interspaces, and that is in the neighbourhood of a "limestone dyke," seven or eight of which have penetrated the vertical fissures in the lava. As limestone occurs above the rock, it is more than probable that in this case at least the separating material has come from above. Boulton (1904, p. 158), in describing British pillow-lavas similar in many respects to the present rock, was of the opinion that the limestone came from below.

In places the fragmentary matter makes up most of the rock, with a scattered pillow here and there; elsewhere pillows are massed together and the group is isolated in a matrix of the finer tufaceous-looking material, while the greater portion of the pillows are grouped in a fashion similar to the lower pillow-lava.

The occurrence of fossiliferous limestone between the pillows at Oamaru Cape, together with the fossiliferous tuffs and limestones above and below the lower lava, undoubtedly point to eruption under submarine conditions. The glassy selvage which is everywhere present indicates rapid cooling of the masses, and this would take place in contact with water. The differences in the structure of the two rock-masses just described evidently point to some difference in the mode of eruption. Reid (1907, p. 51) says, "It is still a moot point whether pillow-lavas are true outflows or are intruded sills." Tempest Anderson (1910, p. 632) witnessed the formation of the pillows as the lava entered the water at Savaii. Geikie (1897) and Teall (1899) ascribe the structure to intrusion into loosely compacted sediments. Benson (1915, p. 125) recognized intrusive contacts with the surrounding sediments in the Nundle district, New South Wales. In the present case the lower lava may be intrusive, but there is no positive evidence to support this view, except the fact that there is no sign of explosive action in the mass, as there is in the upper lava. The indications in the field strongly suggested that the latter rock after coming into contact with the water, and after the invidualization of the pillows, underwent disintegration through local explosions in the mass of the flow, the resulting fragments then settling down through the water and becoming incorporated in the main mass as it flowed over the sea-bottom. After cooling, the rock became fissured, and the subsequently deposited calcareous mud penetrated and filled the cracks, forming dyke-like masses. Pillow-lavas, although frequently occurring as deep-sea lava-flows, are not restricted to conditions of great depth, for Tempest Anderson observed the lava flowing into the sea at Savaii. The nature of the sediments above and below the upper lava at Oamaru clearly indicate shallow-water conditions. In fact, there is reason to believe that the rocks of the Oamaru series were all deposited in comparatively shallow water.

VII. Chemical and Petrographical Notes.

Some preliminary work has been done on the microscopical characters of these pillow-lavas, and chemical analyses made of one of the freshest types from Awamoa Creek near Deborah. More detailed field work is necessary before a full account can be given of these rocks.

Analyses of Pillow-lava, Awamoa Creek.

	Interior of Pillow.	Tachylytic Selvage.
SiO_2	49·7	50·6
Al_2O_3	18·6	17·55
Fe_2O_3	3·2	1·11
FeO	8·15	11·3
MgO	8·62	7·92
CaO	8·2	8·4
Na_2O	1·24	1·13
K_2O	0·61	0·55
H_2O + ...	2·25	1·23
	100·57	99·79
H_2O –	0·79	0·52

The specific gravity of the tachylytic selvage was found to be 2·74, while that of the interior of the pillow was higher, 2·83. This is in accordance with Hutton's results for the similar rock at the lighthouse, his figures being 2·72 and 2·80 respectively (1887, p. 416).

The pillow-lavas at Awamoa Creek (near Deborah) and at the lighthouse near the breakwater show much the same character. In the field there is noticeable on each pillow a distinct black resinous-looking selvage about 1 in. in thickness, while the central portion has all the characteristics of a basalt.

A number of sections have been made from these rocks, and as far as examined they present several features of some interest: it is possible to trace the gradual changes from a basaltic glass with a few phenocrysts, undoubtedly of intratelluric origin, to a holocrystalline dolerite, in which the phenocrysts display a similar attitude towards a completely crystalline ground-mass.

The extreme edge of the tachylyte selvage consists of light brownish-yellow glass in which small porphyritic labradorite crystals and larger crystals of olivine occur as phenocrysts. Skeleton crystals of a basic feldspar also occur, and minute granules of magnetite are scattered sparingly through the glass, which is irregularly fissured. The olivine is almost invariably corroded by the ground-mass, and some of the crystals are penetrated deeply by the glassy base, this being particularly noticeable in the case of the larger ones. Flow-structure is indicated by the parallel alignment of the feldspars. In a section cut farther from the edge the feldspars are bordered by a dark-brown fringe, giving a shadowy extinction between crossed nicols. Under a high power this resolves itself into minute spicules arranged radially around the feldspars. Where the growth has occurred around a minute feldspar there is an approach to a spherulitic arrangement, and an indistinct black cross is seen when the nicols are crossed. It is noticeable that the glass is not bleached on the periphery of this aggregation of crystallites, as is frequently the case in spherulitic tachylytes. Near the centre of the pillow the glass has completely disappeared, and the ground-mass consists of this fibrous brown material shot through with innumerable skeleton feldspars in all stages of growth, the whole enclosing the same minerals that were developed porphyritically in the tachylitic variety of the rock. Still nearer the centre of the spheroid the ground-mass becomes lighter in colour, and rods of magnetite are plainly distinguishable in a faintly

polarizing base. Another slide from the centre of one of the larger pillows possessed similar characteristics in parts, but augite in bladed ragged forms occupied the same relative position in regard to the feldspars that the spicular growth did in the other sections. The last two varieties of the rock can be paralleled exactly in sections cut from the intrusive rock in Oamaru Creek, west of Hutchinson Quarry. This rock is found to vary in different parts of its mass, however, and a specimen taken from the lower quarry was holocrystalline, and the augite enclosed the feldspars ophitically. The rock shows another variation, in that larger feldspars and olivines are embedded in a mass of granular augite and smaller feldspars. This specimen is much coarser in texture than the other varieties. This granulitic variety of the dolerite is probably due to movement towards the end of the process of consolidation, while the ophitic type indicates that the cooling took place under quiescent conditions.

Pillow-lavas invariably belong to the group of intermediate or basic igneous rocks. Among the Palaeozoic rocks well-developed pillow-lavas are of frequent occurrence in Great Britain and are known as "spilites." These rocks are characterized by their richness in soda and poverty in potash, and mineralogically by the abundance of a soda-feldspar. Albite is the principal constituent, next in importance is augite, and olivine occasionally occurs. There is frequently a glassy base, occasionally the feldspars are microporphyritic, and often those of the ground-mass have pointed or acicular forms. Sometimes they consist almost wholly of feldspar laths with a fluidal arrangement. In some types the augite may occur as irregular masses enclosing the ends of feldspar rods, producing a subophitic structure. Diabases, representing the intrusive magma, invariably occur with these rocks. Flett (1911, p. 246) considers that the characteristic feldspar of these rocks, albite, is due to the action of pneumatolytic emanations containing water with soda and silica in solution upon the basic feldspars soon after the rocks had solidified. Further, he states that the spilitic suite of rocks are essentially rocks of districts that have undergone a long-continued and gentle subsidence.

The Tertiary pillow-lavas at Oamaru contain no albite, and this is confirmed by chemical analysis, which shows that the present rocks are remarkably poor in soda, but, like the spilites, remarkable for their poverty in potash. Their structure and mineralogical composition can be paralleled in the spilites, except, of course, for the absence of albite. The rocks were erupted under submarine conditions, but the water was shallow. The association with the intrusive olivine dolerite is analagous to the association of variolitic pillow-lavas with diabases in Anglesey and Cornwall. Yet the poverty of the rock in soda precludes its classification as a spilite.

VIII. Conclusion.

1. There are three horizons of igneous rocks—the Waiareka tuffs, Kakanui breccia, and the upper pillow-lava—although the latter two were almost contemporaneous, the breccia being the earlier.

2. The stratigraphical unconformities and "limestone conglomerate" may be explained on the assumption that volcanic islands were rapidly formed and rapidly destroyed.

3. The unconformities introduced into the sequence by former observers are merely local, and of no significance in classification.

4. The Oamaru series is otherwise conformable throughout.

5. The Oamaru pillow-lavas, like similar rocks in other parts of the world, owe their peculiar structure to eruption and solidification under submarine conditions.

6. These rocks, though similar in some respects to British Palaeozoic pillow-lavas, are clearly differentiated from them by their poverty in soda.

7. The structural and lithological resemblances of the upper pillow-lava at the lighthouse and the pillow-lava in Oamaru Creek are sufficiently strong to justify the assertion that they are at the same horizon. The succession of rocks at the latter place and at Hutchinson Quarry is similar from the lava to the top of the Hutchinson Quarry greensand. At the breakwater we get a clear succession of the beds below the lava down to the tuffs. At the Rifle Butts we get a sequence from the Awamoa mudstone down to the tufaceous rocks. Piecing the evidence together, it would seem that the top of the thicker limestone at the Rifle Butts represents the horizon of the upper pillow-lava, and it is probable that the rocks shown below these in figs. 1 and 2 will be found equivalent. The beds are fossiliferous throughout, and careful and more exhaustive collecting should enable this point to be decided.

8. The fossiliferous beds below the upper pillow-lava at the lighthouse are not the equivalent of the fossiliferous beds at Hutchinson Quarry, as asserted by former observers, but are separated from the latter by a considerable thickness of lava, tufaceous beds, limestone, and "limestone conglomerate."

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Art. VIII.—*Geology of the Oamaru-Papakaio District.*

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[*Read before the Wellington Philosophical Society, 19th September, 1917; received by Editors, 31st December, 1917; issued separately, 24th May, 1918.*]

Contents.

I. Description of the Area.

The area (about twenty square miles in extent) with which this paper is mainly concerned is the north-eastern corner of the Province of Otago. It is bounded on the north-east by the valley-plain of the Waitaki River, on the south-east by the sea, on the south by a line drawn east and west through one mile north of Oamaru, and on the west by a line drawn due south through Peebles (see fig. 1).

A considerable portion of the district, particularly between the township of Papakaio and Oamaru, is capped by heavy river-gravels and silts; these are evidently the remnant of a formerly extensive plain which sloped to the south-south-east, as the general trend of the streams that drain the area is in that direction. This former surface has been sculptured into well-rounded ridges and hills, attaining an elevation of 650 ft. near Papakaio in the north, and falling to the 350 ft. level in the south-east. In the north-western part of the district the Ngaparan coal-grits, mudstones, and greensands crop out, and a ridge of quartz gravels in this locality attains a height of over 1,000 ft. Noticeable features of the country south of this ridge are the two well-marked depressions in the vicinity of Tabletop Hill and on the Ardgowan Estate. The Oamaru Creek in flowing over the softer greensands and tuffs of the former locality has by rapid lateral erosion widened its basin considerably, leaving, however, two limestone-capped flat-topped hills standing prominently above the surrounding low-lying area. The stream on leaving this open tract of country becomes much constricted as it flows over the limestone, and at the Devil's Bridge it passes beneath a natural bridge of limestone before it reaches the Ardgowan area, where the softer Hutchinsonian and Awamoan rocks have undergone extensive denudation, forming the second depressed area. The stream then enters the volcanic area north of Oamaru, and its narrow bed is flanked by precipitous cliffs of basaltic rock.

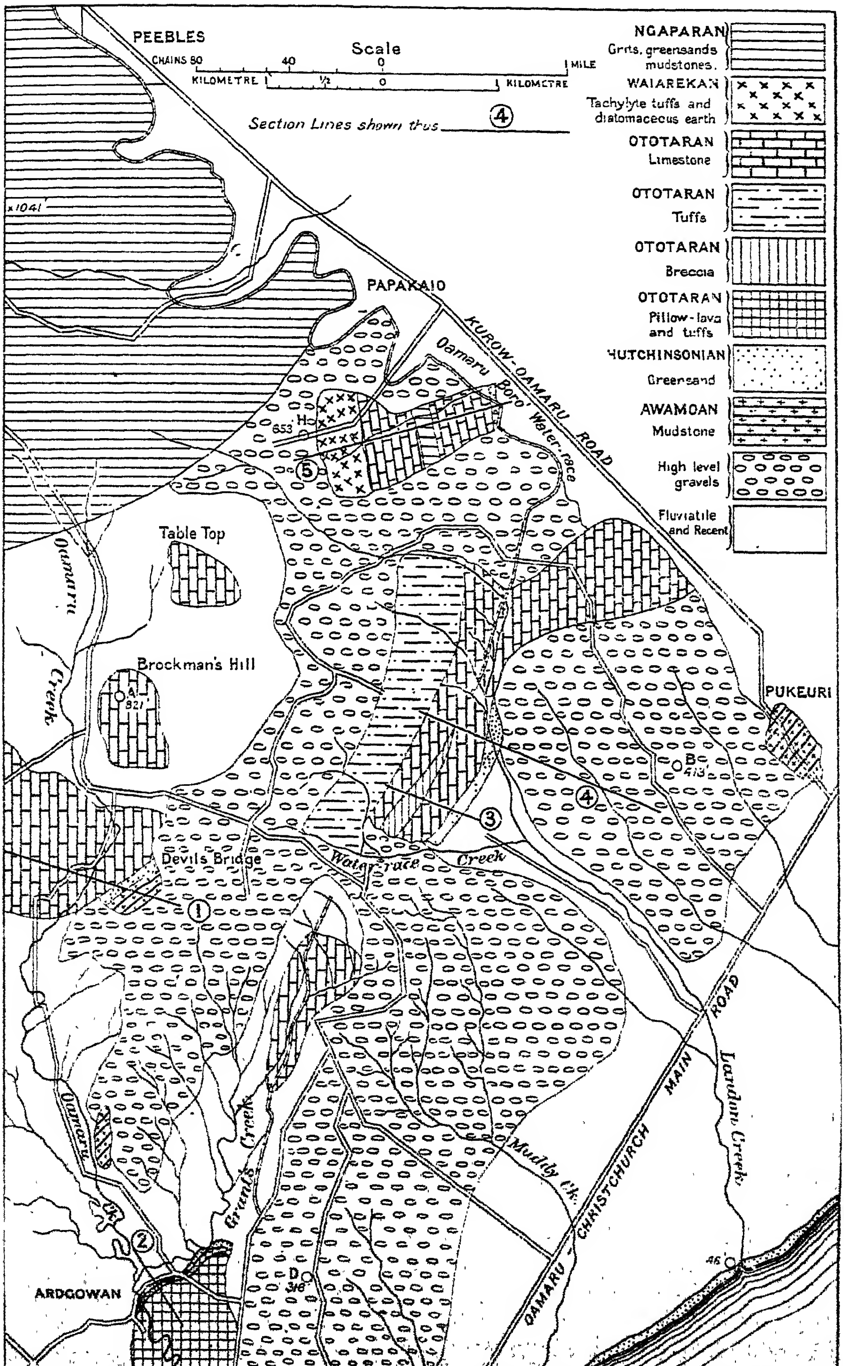

FIG. I.—Geological map of the Oamaru-Papakaio district. In the legend the order of superposition is inverted.

II. Historical Summary.

Although the older Geological Survey did a considerable amount of work in the Oamaru and Waitaki districts of North Otago, little reference has been made to the geology of the Papakaio district.

In 1874 Traill collected fossils at Pukeuri, and Hector (1882, p. 123) assigned the mudstones there to the horizon of the nummulitic beds of the Upper Eocene—that is, he placed them below the Hutchinson Quarry beds. McKay in 1876 made collections at the Devil's Bridge and at Ardgowan. He also examined the limestone at Landon Creek and referred it to the Cretaceo-Tertiary. The volcanic rocks in the watershed between Oamaru and Landon Creek he referred to a horizon higher than the Waiareka tuffs, and rightly ascribed them to the second period of vulcanicity. Park (1905, p. 519), on palaeontological grounds, placed the Pukeuri beds below the limestone, and stated that the limestone at the Devil's Bridge overlay the Hutchinson Quarry beds. Marshall and Uttley (1913, p. 303), on palaeontological and stratigraphical evidence, placed the Pukeuri beds above the limestone—that is, above the Oamaru beds—and the Hutchinson Quarry beds at the Devil's Bridge also above the limestone.

III. Aim of this Paper.

In 1916, in a paper on the geology of the Kakanui district, I gave a detailed succession of the beds of the Oamaru system east of the Waiareka Valley, and that paper gave some of the observations on which the sequence was based. The Waitaki stone of Professor Park was shown to be the Ototara stone in the locality where he had described it.

It is the aim of the present paper to produce further evidence of post-Waiarekan volcanic activity, to give an account of some hitherto undescribed sections in the Oamaru and Papakaio districts, and to show the relationship of the beds to those in the south of the Oamaru district.

IV. Description of the Sections.

It has already been mentioned that gravel deposits form the surface rock over a great part of the country, but the Tertiary beds crop out in the basins of Oamaru and Landon Creeks, and at several places on the Oamaru–Kurow Road. The sequence is usually clear, but at Papakaio the beds are faulted, and the continuity of an otherwise excellent section is broken.

In the Devil's Bridge area the deposition of the limestone appears to have been continuous from the close of the Waiarekan period to the commencement of the Hutchinsonian; in the other localities to be described, deposition was interrupted by a recrudescence of vulcanicity. It is proposed, therefore, to give an account of the Devil's Bridge section, to be followed by descriptions of sections in the district that show important departures from the normal sequence as represented in that area.

1. *Devil's Bridge.* (Fig. 2.)

Fig. 2 represents a section from the Devil's Bridge in a west-north-west direction to a point about a mile beyond the area mapped, so as to include the Waiarekan beds.

The tuffs (*a*) are very fine and tachylytic, and are interbedded with bands of diatomaceous earth. Dykes and sills intersect the tuffs and the

diatomaceous earth, and the latter is altered in places to a hard flinty rock. There are inclusions of quartz in the dolerite, this being a noticeable feature of the earlier intrusive rocks associated with the Waiareka tuffs. The quartz has probably been incorporated during the passage of the molten rock through the quartz grits that lie at the base of the Tertiary series. The limestone is poor in fossils, and is similar to the building-stone, but in parts it becomes chalky. A peculiar nodular surface marks the junction of this rock with the overlying greensand, although it is not so conspicuous in this locality as in other parts of the district. The greensand (*c*) overlying is glauconitic, casts of Foraminifera being plentiful. Some distance above the base *Pachymagas parki* (Hutt.) occurs in abundance, other fossils being scarce. The brown sands (*d*) are also glauconitic

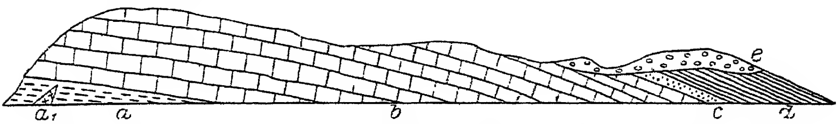

FIG. 2.—Section (diagrammatic) W.N.W.-E.S.E. through the Devil's Bridge. (*a*) Tuffs and diatomaceous earth, intruded by dolerite (a_1); (*b*) limestone; (*c*) greensand; (*d*) Awamoa beds; (*e*) gravels.

and very fossiliferous. The nodular band contained *Terebratula* sp., *Aetheia gualteri* (Morris), *Hemithyris* sp., and stems of *Isis*. The greensand (*c*), in addition to *Pachymagas parki* (Hutt.), contained *Pecten huttoni* Park. The fossils from the brown sands (*d*) have been recorded by Marshall and Uttley (1913, p. 303) and clearly indicate that the beds are Awamoan.

Park (1905, p. 518), in describing the beds here, placed the limestone above the Hutchinsonian and Awamoan; but the greensands lie hard upon the surface of the limestone, which is undoubtedly the Ototara stone. The rocks are conformable throughout, and dip towards the coast at an angle of from 10° to 16°.

2. *Grant's Stream, Ardgowan.* (Fig. 3.)

At Ardgowan, near the junction of Grant's Stream with the Oamaru Creek, a small section is exposed on the roadside. The lowest beds (*a*) consist of a brecciated pillow-lava, which can be traced in a continuous section along the banks of Oamaru Creek to the town of Oamaru. This bed is overlain by a limestone (*b*) 10 ft. thick, containing occasional water-worn masses of decomposed vesicular basaltic rock. This passes into an indurated limestone (*c*), which becomes nodular at its junction with the greensand (*d*). The nodular portion contains many fossils, but chiefly as casts. Stems of *Mopsea* also occur. The actual junction with the overlying greensand (*d*) is not seen, as the latter occur separated from the main exposure. From the nodular surface of the limestone I obtained the following forms: *Turbo* sp., *Polinices* sp., *Turritella* sp., *Lima lima* (L.), *Ostrea* sp., *Cardium* sp., *Liothyrella boehmi* Thomson, *Terebratulina suessi* (Hutt.), *Aetheia gualteri* (Morris), *Hemithyris* sp. The section is interesting as it indicates clearly the horizon of the volcanic rocks, which are here about 20 ft. below the nodular bed.

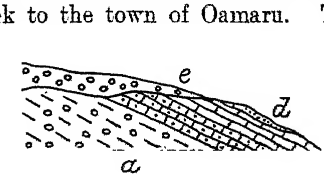

FIG. 3.—Section at Ardgowan. (*a*) Brecciated pillow-lava, &c.; (*b*) limestone (with rounded boulders); (*c*) limestone; (*d*) greensand; (*e*) gravels.

3. *Water-race Creek, Oamaru District.* (Fig. 4.)

This creek is a tributary of Landon Creek. The rocks cover an area of about half a square mile, and the exposure is isolated, but it is quite possible to determine the horizon of the upper beds. The section is noteworthy, as it shows a bed of limestone of considerable thickness between two beds of fragmental volcanic rocks. The beds dip E. 30° S., at an angle varying from 10° to 16°.

The tuffs (*a*) are greenish-brown, much weathered, and cemented by crystalline calcite. They are finer than the breccia higher in the section, and do not contain the same variety of minerals. The limestone (*b*) is tufaceous in parts, sometimes containing distinct bands of calcareous tuff.

Bed (*c*) is a thick breccia similar in character to the "mineral breccia" of the Kakanui locality (*cf.* Uttley, 1916, p. 20). This is overlain by a limestone which becomes glauconitic and fossiliferous towards the top. The fossils obtained were: *Epitonium lyratum* (Zitt.), *Pecten delicatulus* Hutt., *P. polymorphoides* Zitt., *Liothyrella boehmi* Thomson, *L. landonensis* Thomson, *Murravia catinuliformis* (Tate), *Terebratulina suessi* (Hutt.). *Pachymagas ellipticus* Thomson, *Rhizothyris rhizoida* (Hutt.), *Hemithyris* sp., *Aetheia gaulteri* (Morris).

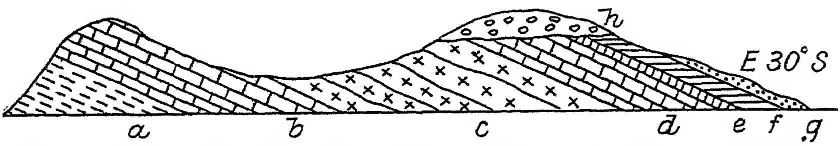

FIG. 4.—Section, Water-race Creek, Oamaru District. (*a*) Tuffs; (*b*) limestone; (*c*) calcareous mineral breccia; (*d*) limestone, glauconitic and fossiliferous in its upper portion; (*e*) limestone band; (*f*) greensand; (*g*) hard brachiopod band; (*h*) river gravels.

This bed is followed by a very hard white limestone (*e*) about 18 in. thick.

The greensand (*f*) overlying is crowded with brachiopods. The following fossils were collected here: *Pecten hutchinsoni* (Hutt.), *P. huttoni* (Park), *Epitonium lyratum* (Zitt.), *Pachymagas parki* (Hutt.), *Rhizothyris rhizoida* (Hutt).

The bed (*h*), which is really the upper portion of (*g*), is a hardened glauconitic stone. It contained *Pachymagas parki* (Hutt.) and *Pecten huttoni* (Park).

This greensand (*g*) and (*h*) evidently represents the Hutchinson Quarry greensand, while the hard limestone band (*e*) represents the nodular band at Kakanui and All Day Bay (*cf.* Uttley, 1916, pp. 20, 21, 23).

4. *Landon Creek, Papakaio Survey District.* (Fig. 5.)

About a mile west of Trig. Station B, limestone and greensand occur on both banks of Landon Creek. The section across the creek is shown in fig. 5. The beds dip S. 30° E. at 8°, and this would take them beneath the Awamoa beds at Pukeuri cutting.

The lowest bed is a calcareous tuff, which, however, is not exposed in section. The material excavated from the tunnel for the Oamaru–Papakaio water-race is a tuff, and from the position of the tunnel it must lie beneath the limestone. This limestone is at least 50 ft. thick. It is pure and white in it lower portion, but in its upper 20 ft. it becomes glauconitic, and near the junction with the overlying greensand (*c*) there is an alternation of

hard limestone with looser glauconitic sand, giving the rock a flaggy appearance. At their base the greensand (*c*) is intermingled with limestone, and where the former has been removed by weathering an irregular nodular surface is exposed on the surface of the limestone.

From the upper glauconitic portion of the limestone (*b*) I collected the following forms: *Liothyrella boehmi* Thomson, *L. landonensis* Thomson, *Terebratulina suessi* (Hutt.), *Pachymagas ellipticus* Thomson, *Rhizothyris rhizoida* (Hutt.), *Aetheia gualteri* (Morris), and *Hemithyris* sp.

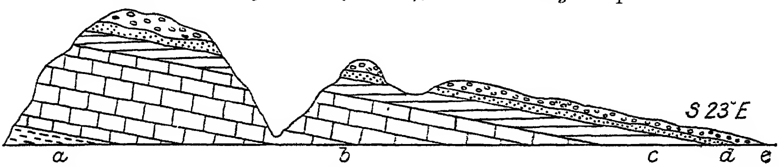

FIG. 5.—Section, Landon Creek, Papakaio district. (*a*) Tuffs; (*b*) limestone; (*c*) greensand; (*d*) hard glauconitic band; (*e*) river gravels.

The greensand (*c*) yielded *Epitonium lyratum* (Zitt.), *Pecten polymorphoides* Zitt., *Terebratulina suessi* (Hutt.), *Pachymagas parki* (Hutt.), *Rhizothyris rhizoida* (Hutt.), *Aetheia gualteri* (Morris), *Hemithyris* sp., and *Mopsea hamiltoni* (Thomson) (?). A hard glauconitic band (*d*) overlies, containing *Pachymagas parki* (Hutt.) and *Rhizothyris rhizoida* (Hutt.).

The sequence in this locality differs somewhat from the section in Water-race Creek, for the breccia is missing, and the hardened limestone in the latter locality is apparently represented by the flaggy limestone in the present section, and the latter is evidently at the horizon of the nodular band in the Kakanui locality.

5. *Flume Creek, Papakaio District.* (Fig. 6.)

This section is exposed near the township of Papakaio in a small gully, spanned by the flume of the water-race. The section is not continuous, and the dip of the rocks in the lower part of the creek varies somewhat. There are distinct signs of faulting in the neighbourhood. At the head of the gully a bed of diatomaceous earth crops out, and lower down a small exposure on the left shows the same bed lying beneath a fine calcareous tachylytic tuff, dipping N. 70° E. at 20°. Greenish-brown laminated tuffs (*c*)

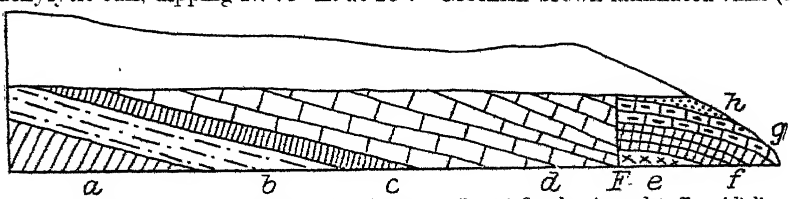

FIG. 6.—(*a*) Diatomaceous earth; (*b*) tachylyte tuff; (*c*) fine laminated tuffs; (*d*) limestone; (*e*) tuffs; (*f*) glauconitic limestone; (*g*) hardened limestone; (*h*) greensand; (F) fault.

overlie, and then follows a flaggy limestone (*d*). There is a break in the section at this point, but tuffs containing minerals occur *in situ* at the bottom of the bank. Then follows a coarser and more glauconitic limestone, which has a steeper dip than the lower flaggy limestone. A hard band of limestone (*g*) about 15 ft. thick caps the more glauconitic stone. Greensand (*h*) lies hard upon (*g*), and the junction is marked by the great abundance of the stems of *Mopsea*.

The greensand yielded *Epitonium lyratum* (Zitt.), *Terebratulina suessi* (Hutt.), *Pachymagas parki* (Hutt.), *Aetheia gualteri* (Morris), and *Hemithyris* sp.

In this locality also we have the nodular band occurring at the base of the greensand, and notable for the abundance of alcyonarian stems. Dr. Thomson informs me that a nodule collected by him from this locality was analysed by Mr. B. C. Aston and showed 1·8 per cent. P_2O_5, equivalent to 2·9 per cent. $Ca_3P_2O_8$.

V. Summary.

(*a.*) There has been at least one period of vulcanicity subsequent to the Waiarekan tuffs. It is more than probable that there were two periods of eruption, the mineral breccia of Kakanui being the record of the first, while the volcanic rocks at Grant's Creek indicate the last phase. This is not so evident in the present area, as nowhere are the two types of volcanic rocks represented in the same section, although the breccia at Water-race Creek is certainly farther down in the limestone than the volcanic rocks at Ardgowan. In the town of Oamaru, however, the intrusive rocks cut across interbedded limestone and breccia beds.

(*b.*) The mineral breccia of Kakanui (see Thomson, 1906) extends into the Papakaio district, and forms a well-marked stratigraphical horizon throughout the whole Oamaru coastal district.

(*c.*) The diatomaecous-earth deposits occur at Papakaio associated with tachylite tuffs, as in the earlier known deposits in Cave Valley. This represents a considerable extension of its range.

(*d.*) The nodular band is persistent throughout the Oamaru and Papakaio districts from Kakanui to Papakaio, a distance of about twenty miles, and is phosphatic at both these localities. As a hardened band of limestone often underlies it, and has been proved phosphatic by Morgan (1915) at Hutchinson Quarry, it may reward investigation elsewhere.

(*e.*) In the Papakaio district there is no evidence of two distinct limestones separated by the Hutchinson Quarry and Awamoa beds, as contended by Park (1905).

(*f.*) Dr. Thomson informs me that the fauna beneath the Maerewhenua limestone, farther up the Waitaki Valley, bears a strong resemblance to that of the upper part of the Ototara stone in the Landon Creek area. Detailed stratigraphical work between Papakaio and the Maerewhenua districts should therefore go far towards settling the vexed question of the relationship between the Oamaru and Waitaki stones. There are many excellent natural sections in the Maerewhenua district that have not yet been described.

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ART. IX.—*Descriptions of New Species of Lepidoptera.*

BY ALFRED PHILPOTT.

Communicated by Dr. W. B. Benham, F.R.S.

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HYDRIOMENIDAE.

Hydriomena canescens n. sp.

♂. 29 mm. Head, palpi, thorax, and abdomen rather dark grey. Antennae, ciliations 1. Legs grey, tarsi annulated with ochreous-white. Forewings triangular, costa subsinuate, apex obtuse, termen subsinuate. oblique, *brownish-grey*: a broad curved basal band obscurely paler; *veins interruptedly blackish*: second line thin, obscure, ochreous, anteriorly margined with white; indications of alternate ochreous and white lines between this and termen; a black line round termen, interrupted by ochreous dots on veins: cilia dark grey with a faint paler median line. Hindwings whitish-grey, darker terminally: numerous alternate waved darker and paler lines; terminal area and cilia similar to forewings.

Near *H. hemizona* Meyr., but the ground-colour is wholly different, and there are many minor distinctions.

Queenstown, in March. A single specimen taken by Mr. M. O. Pascoe, in whose collection the type remains.

H. praerupta n. sp.

♂. 33–34 mm. Head yellowish-green. Palpi yellowish-green mixed with brown. Antennae brown, ochreous-tinged. Thorax yellowish-green mixed with black. Abdomen ochreous. Legs ochreous-grey, more or less infuscated. Forewings triangular, costa moderately arched, apex obtuse, termen slightly bowed; *yellowish-green; markings dark olive-green*; a curved irregular band near base, preceded by an obscure line; space between basal and median bands pale ground-colour with suffused dark median area; median band broad, anterior margin curved, with strong indentations above and below middle, posterior margin irregularly curved, *with strong bidentate projection at middle*; subterminal line greenish-white, subdentate, broadly margined anteriorly with dark suffusion which almost touches projection of median band, thus nearly interrupting the stripe of pale ground-colour; an oblique dark striga from below apex to terminal line, *deliminating a pale subtriangular apical patch*; a crenate blackish terminal line: cilia yellowish-green with some dark scales. Hindwings grey-whitish; a waved fuscous median line and several similar but imperfect preceding and following lines; a thin blackish crenate line on termen: cilia ochreous-grey.

Closely related to *H. callichlora* (Butl.), from which it can be best separated by the pale apical area, the more dentate subterminal line, and the stronger projection of the posterior margin of the median band. The species may be regarded as the mountain representative of *callichlora*.

Mount Cleughearn, Hunter Mountains. Two males in January, 1916. A single male in Mr. M. O. Pascoe's collection was taken at Lake Howden in November, 1912. Type in coll. A. Philpott.

Notoreas incompta n. sp.

♂ ♀. 26–31 mm. Head, palpi, thorax, and abdomen white densely irrorated with black. Antennae black, finely annulated with white, *pectinations in ♂ rather short.* Legs black, irrorated with white, tibiae and tarsi annulated with ochreous-white. Forewings triangular, costa subsinuate, termen evenly rounded, oblique, *white, densely irrorated with black,* especially on median band and terminal area; an irregular curved black basal line, median portion mixed with brownish-ochreous; an obscure double dentate evenly-curved black line at $\frac{1}{4}$; median band more or less suffused with ochreous, inner margin waved, regularly curved, outer margin twice angularly projecting above middle, more or less incurved beneath; subterminal line obscure, interrupted, white; veins blackish interrupted with white: cilia white barred with black and with a thin median black line. Hindwings greyish-fuscous, terminal area dark fuscous; a pale median fascia and some obscure darker lines on apical half; in some specimens the median area is tinged with brownish-ochreous: cilia as in forewings. Undersides grey-whitish, terminal area broadly fuscous; a black discal dot; some obscure waved dark lines before middle; a prominent waved irregularly-curved black line beyond middle; subterminal line more distinct than on upper surface.

Hardly distinguishable in coloration from *N. orphnaea* (Meyr.), but easily separable by the shorter antennal pectinations and the lesser development of the palpal hairs. It is considerably larger than *N. anthracias* (Meyr.), and the markings are less clearly defined.

I am indebted to Mr. R. Gibb, Curator of the Southland Museum, for the opportunity of describing this interesting form, two of each sex having been taken by him on the Kepler Mountains, at an elevation of about 3,000 ft., in January. Types, ♂ (1483) and ♀ (1484) in coll. Southland Museum.

PYRAUSTIDAE.

Scoparia declivis n. sp.

♂. 28–32 mm. Head, palpi, and thorax brown densely sprinkled with white. Antennae brown. Abdomen pale whitish-ochreous, grey beneath. Legs grey mixed with fuscous, tarsi with pale annulations. Forewings elongate, triangular, costa hardly arched, subsinuate, apex obtuse, termen almost straight, rounded beneath; *fuscous-brown irrorated with white;* basal area to first line rather pale; *first line whitish, straight, outwardly oblique;* stigmata obscure or obsolete; reniform represented by a dark transverse mark; second line curved, deeply indented beneath costa, white; subterminal broad, parallel to termen, suffused, whitish; a series of indistinct dark dots round termen: cilia grey with two fuscous lines. Hindwings pale whitish-ochreous: cilia pale whitish-ochreous with two darker lines.

A browner species than *S. petrina* (Meyr.), and differing also in the straight first line.

The type specimen was taken at Commissioners Creek (Wakatipu) in February by Mr. W. G. Howes. I have also an example from Macetown, taken, also in February, by Mr. H. Hamilton.

Scoparia scripta n. sp.

♂ ♀. 29–32 mm. Head ochreous-grey-whitish. Palpi moderate, maxillaries white, labials white within, brownish-black without. Antennae ochreous-whitish, ciliations in ♂ $\frac{3}{4}$. Thorax brownish-grey. Abdomen ochreous-whitish. Legs ochreous-white, much infuscated, tarsi banded with fuscous.

Forewings elongate, triangular, costa subsinuate, apex subacute, termen sinuate, slightly oblique, rounded at tornus; pale ochreous densely sprinkled with fuscous and more or less suffused with white on costal half; a thick black basal streak from costa, curving to centre of wing, thence straight to about $\frac{1}{4}$, apex acute; first line faintly whitish, posteriorly fuscous-margined, from costa at $\frac{1}{4}$ strongly outwardly oblique for about $\frac{2}{3}$, thence sharply angulated to dorsum before middle; *orbicular large, touching first line, oval, black, pale-centred, lower half thick, prominent, upper half hardly traceable;* claviform obsolete; *reniform irregularly X-shaped, large, black, upper and lower halves filled with fuscous, inner lower arm produced so as sometimes to touch orbicular;* second line indistinctly whitish, preceded by a series of cuneate black dots, sharply indented beneath costa; a series of roundish black dots on termen: cilia ochreous mixed with fuscous: two indistinct darker lines. Hindwings pale whitish-ochreous; lunule, subterminal line, and terminal band infuscated: cilia as in forewings but rather paler.

Closely related to *S. rotuella* (Feld.) and *S. clavata* Philp. From the former it may be distinguished by the disconnected orbicular and reniform, and from the latter by the acutely pointed basal streak.

Hunter Mountains, in January. Four males and one female taken in damp gullies at about 3,000 ft

Scoparia caliginosa n. sp.

♂. 17 mm. Head, palpi, antennae, and thorax ferruginous-brown mixed with grey. Abdomen ferruginous-brown. Legs grey-brown, tarsi obscurely annulated with paler. Forewings moderate, triangular, costa almost straight, apex obtuse, termen straight, slightly oblique, ferruginous-brown densely irrorated with whitish on basal $\frac{3}{4}$; a short oblique brown fascia from costa at base; first line obscurely paler, curved, indented at middle, suffusedly margined posteriorly with ferruginous-brown; orbicular indistinct; claviform irregular, blackish on fold; reniform obscurely 8-shaped, ferruginous-brown, pale-centred; *second line parallel to termen, subsinuate, interruptedly margined with ferruginous-brown anteriorly, whitish;* subterminal line close to termen, indistinct, whitish: cilia fuscous-grey with darker basal line. Hindwings fuscous-grey, darker terminally: cilia grey with two darker lines.

Near *S. ergatis* Meyr. and *S. organaea* Meyr., but separated from both by the form of the second line.

A single male received from Mr. J. H. Lewis. Locality doubtful, but probably Matakanui.

TORTRICIDAE.

Eurythecta curva n. sp.

♂. 14–15 mm. Head and palpi ochreous. Antennae fuscous, ciliations $2\frac{1}{2}$. Thorax whitish-ochreous. Abdomen grey-whitish, anal tuft ochreous. Legs ochreous-whitish. Forewings, costa strongly arched at base, apex round-pointed, termen straight, oblique *ochreous-whitish with scattered fuscous scales; a rather bright ochreous mark in disc above middle from $\frac{1}{3}$ to $\frac{2}{3}$;* sometimes a similar but more obscure mark below middle; the fuscous scales sometimes tend to form lines on veins: cilia whitish-ochreous with two darker lines. Hindwings, termen markedly sinuate, greyish-fuscous: cilia as in forewings.

Nearest to *E. eremana* (Meyr.), but differing in size and wing-shape.

Hunter Mountains, in January. Fairly common on low herbage at 3,500 ft.

Epichorista theatralis n. sp.

♀. 14 mm. Head, palpi. and thorax ochreous. Antennae fuscous, annulated with ochreous towards base. Abdomen fuscous-grey. Legs grey-whitish. Forewings moderately arched at base, apex rectangular, termen almost straight, hardly oblique, *rather bright ochreous; markings silvery metallic but rendered obscure by an admixture of ground-colour;* a broad fascia from $\frac{1}{4}$ costa to $\frac{1}{2}$ dorsum; a narrow fascia from $\frac{1}{2}$ costa, strongly outwardly oblique to middle of wing at $\frac{3}{4}$, thence angled downwards to dorsum before tornus; a slightly curved subterminal line: cilia bright ochreous. Hindwings dark greyish-fuscous: cilia greyish-fuscous with a darker basal line, ochreous round apex.

Apparently nearest to *E. emphanes* (Meyr.), but entirely different in coloration. A single male being all the material available, the generic position of the species must for the present be regarded as provisional.

Hunter Mountains, in January. The type was secured in *Nothofagus* forest at about 2,750 ft.

GELECHIADAE.

Gelechia sparsa n. sp.

♂. 10–11 mm. Head and thorax white densely mixed with brown. Palpi white, brown beneath. Antennae fuscous with some admixture of whitish. Abdomen fuscous. Legs pale fuscous, tarsi obscurely annulated with whitish. Forewings elongate, narrow, costa slightly arched, apex acute, termen extremely oblique: *white densely irrorated with fuscous and ferruginous-brown; an outwardly-oblique ferruginous-brown fascia from middle of dorsum, reaching half across wing; a blotch of similar colour at tornus:* cilia grey-whitish sprinkled with fuscous. Hindwings, termen strongly and angularly emarginate, fuscous: cilia fuscous-grey.

Not closely approaching any other *Gelechia;* perhaps nearest to *G. glaucoterma* Meyr.

Dunedin, in November. Three males taken by Mr. C. C. Fenwick, whose collection contains the type.

OECOPHORIDAE.

Borkhausenia honorata n. sp.

♂. 12 mm. Head, palpi, antennae, and thorax dark bronzy-brown. Abdomen dark fuscous. Legs fuscous, tarsi annulated with yellow. Forewings moderate, costa moderately arched, apex obtuse, termen rounded, oblique, dark fuscous-brown; *a broad yellow stripe along dorsum, indented above before middle and tornus; an irregular yellow blotch beneath costa at $\frac{1}{3}$ and a similar one before $\frac{2}{3}$,* both sometimes absent; *a broad straight yellow fascia from costa at $\frac{4}{5}$, parallel to termen, reaching $\frac{2}{3}$ across wing:* cilia fuscous. Hindwings and cilia dark fuscous.

Allied to *B. chrysogramma* Meyr., but differing entirely in the arrangement of the yellow markings.

Two examples secured in the neighbourhood of Invercargill, and a third at Knife and Steel Boat-harbour (Fiord County). All taken in forest in December. Mr. G. V. Hudson has a specimen from Lake Harris, taken in January, 1906, this being the first of the species to be brought to light.

Borkhausenia sabulosa n. sp.

♂ ♀. 10–11 mm. Head, palpi, thorax, and abdomen greyish-brown. Antennae greyish-brown annulated with darker. Legs grey-brown, tarsi obscurely annulated with ochreous. Forewings moderate, in ♀ lanceolate,

costa strongly arched, apex obtuse, termen very oblique, *greyish-brown with numerous scattered ochreous scales, especially in ♀; in ♂ thickly and irregularly sprinkled with fuscous-brown:* cilia grey with fuscous sprinkling. Hindwings fuscous-grey: cilia grey with darker basal line.

Approaches *B. melanamma* Meyr., but is smaller, and differs in the peculiar speckled appearance.

Central Otago. Taken commonly by Mr. J. H. Lewis, to whose liberality I am indebted for the type of the species.

Trachypepla semilauta n. sp.

♂♀. 15–16 mm. Head ochreous-white. Palpi ochreous-white infuscated at base beneath and with a fuscous band before apex. Antennae fuscous, obscurely annulated with ochreous, ciliations in ♂ $2\frac{1}{2}$. Thorax fuscous mixed with ochreous. Abdomen fuscous-grey. Legs whitish-grey with some infuscation. Forewings rather broad, costa moderately arched, apex subacute, termen almost straight, strongly oblique; *white, faintly tinged with yellowish; base narrowly fuscous-black, extending on costa to $\frac{1}{5}$; an outwardly-angulated fuscous-black fascia from dorsum at middle, not reaching costa, broadest on dorsum where it is sometimes bright ochreous; a triangular black fascia from costa at $\frac{1}{2}$, its apex, which encloses a white spot, reaching centre of wing, thence continued as a line to tornus;* a small black mark preceding this below middle; a curved black fascia from costa at $\frac{3}{4}$ round termen to tornus, anteriorly margined with white, the space between this and the median fascia being filled with bright ochreous; a black apical blotch; in some specimens the space between the costal fasciae is suffusedly filled with dark fuscous, the ochreous and white colouring being almost obsolete: cilia whitish-ochreous more or less sprinkled with fuscous; apex fuscous. Hindwings dark greyish-fuscous: cilia grey-fuscous with darker basal line.

Distinguished from *T. ingenua* Meyr., its nearest ally, by the white basal area of forewings.

Hunter Mountains, in January. Three specimens beaten from undergrowth in *Nothofagus* forest at about 2,750 ft.

HELIODINIDAE.

Thylacosceles radians n. sp.

♂♀. 8–$9\frac{1}{2}$ mm. Head and palpi shining white. Antennae white, infuscated on apical third. Thorax grey-whitish. Abdomen ochreous-whitish, apical half in ♂ dark fuscous. Legs white, tibial fringe black. Forewings moderate, parallel-sided, costa hardly arched, apex acute, termen extremely oblique, *leaden fuscous, somewhat ochreous-tinged in* ♀; an obscure suffused white blotch in disc at $\frac{3}{4}$, sometimes preceded by a white spot on tornus: cilia fuscous. Hindwings and cilia grey-fuscous.

Smaller and darker than *T. acridomima* Meyr.

Seaward Bush (Invercargill). Fairly common in December. *T. acridomima* is attached to the fern *Aspidium aculeatum* var. *vestitum*, and it is possible that the food plant of *T. radians* is *Polypodium diversifolium*, which, with other epiphytic growth, frequently covers the trunks of the kamahi.

GLYPHIPTERYGIDAE.

Hieroderis (?) stellata n. sp.

♂. 20 mm. Head ferruginous-brown. Palpi dark fuscous, apex of second joint beneath and apex of terminal joint whitish. Antennae

narrowly annulated with ferruginous-brown and white. Thorax, anterior half dark cupreous with purplish sheen, posterior half white. Abdomen greyish-fuscous. Legs fuscous-grey, anterior pair darker, tarsi broadly annulated with white. Forewings, costa strongly arched, apex rounded, termen subsinuate, little oblique, rounded beneath; *shining cupreous; markings white;* an irregularly-triangular basal patch on lower half of wing, its upper edge indented; a round spot beneath costa at $\frac{1}{4}$; a chain of small spots from costa at $\frac{1}{2}$ curving round to costa at $\frac{5}{8}$; an inwardly-oblique series of two or three spots from costa at $\frac{7}{8}$; a dot on costa before apex; a large triangular patch on dorsum before middle, its apex reaching to centre of wing and its base broadly bifid; a round spot on dorsum at $\frac{1}{2}$, followed by a series of spots which curve round to tornus: cilia cupreous with white patches beneath apex and at tornus. Hindwings elongate-ovate; dark fuscous: cilia paler, with obscure dark basal line and tips whitish round apex.

Very handsome and distinct. The generic position is provisional; the species probably belongs to a genus not hitherto recorded from New Zealand.

Blue Cliff (Fiord County). A single specimen taken in January by Mr. C. C. Fenwick. It was captured in a bush track after dark. Type in coll. C. C. Fenwick.

Glyphipteryx barbata n. sp.

♂. 15–20 mm. Head and thorax fuscous-grey. Palpi fuscous-grey, *second joint with dense rounded tuft of long hair.* Antennae blackish. Abdomen fuscous-grey, segmental divisions and anal tuft paler. Legs fuscous-grey, tarsi annulated with fuscous and whitish. Forewings elongate-ovate, costa strongly arched, apex acutely projecting, termen extremely oblique; *fuscous-grey with faint brassy sheen; a white median stripe from base to beneath apex, becoming obsolete towards extremities;* apical $\frac{1}{3}$ of costa more or less whitish with three or four dot-like strigae near apex: cilia fuscous-grey with obscure darker basal line. Hindwings fuscous-grey: cilia fuscous-whitish, paler round apex.

Superficially very like *G. bactrias* Meyr., but at once distinguished by the tufted palpi.

Discovered by Mr. C. E. Clarke, who found it fairly common at Waitati (Dunedin) in November. Type in coll. C. E. Clarke.

HYPONOMEUTIDAE.

Zelleria rorida n. sp.

♂ ♀. 13–15 mm. Head and palpi white densely sprinkled with ochreous. Antennae brown. Thorax white mixed with ochreous. Abdomen grey-whitish. Legs grey-whitish, anterior pair infuscated. Forewings elongate, of uniform breadth, costa slightly arched, apex subacute, termen very oblique, *pale greyish-ochreous irrorated with blackish-brown,* an irregular interrupted white suffusion along dorsum, continued up lower half of termen; three series of blackish-brown spots from base to termen, sometimes more or less obsolete, first on costa, second on upper median vein, third on lower median; sometimes a similar series below fold; a broad inwardly-oblique brown fascia from costa to dorsum at $\frac{1}{3}$; a semi-oval brown spot on dorsum at $\frac{1}{2}$; *an irregular white blotch on costa near apex:* cilia ochreous-grey, brown round apex. Hindwings grey: cilia ochreous-grey.

Differs from *Z. sphenota* (Meyr.) in the presence of the preapical white blotch.

Bluff and Invercargill, in coastal forest; a male and female in November. Mr. J. H. Lewis has taken the species in Central Otago.

PLUTELLIDAE.

Dolichernis jubata n. sp.

♂. 14 mm. Head ochreous. Antennae ochreous, annulated with fuscous. Palpi ochreous mixed with brown, terminal joint brownish. Thorax ochreous, shoulders brownish-black. Abdomen ochreous-grey. Legs ochreous-grey, anterior tarsi fuscous annulated with ochreous. Forewings elongate, costa strongly and evenly arched, apex obtuse, termen rounded, oblique; *light ochreous; markings blackish brown;* a broad stripe along costa, irregular beneath, interrupted before apex, apical spot darker; first discal spot obliquely before plical, touching costal stripe; plical at $\frac{1}{2}$, oviform; second discal transverse, touching costal stripe; a broad fascia along termen, interrupted below apex: numerous scattered dark scales on lower half of wing: cilia ochreous with broad dark basal line. Hindwings grey-whitish: cilia grey with darker line round apex.

Very distinct. The species is placed in *Dolichernis* pending the discovery of further material; with the exception of the proportionate length of antenna to forewing the characters agree very well.

Tisbury, Invercargill. A single male taken in kamahi (*Weinmannia racemosa*) forest in January, 1917. Mr. G. V. Hudson has also a single example, taken at Kaeo in January, 1913. Evidently a wide-ranging though scarce species. Type in coll. A. Philpott.

Orthenches polita n. sp.

♂. 11 mm. Head whitish-brown. Palpi white, brownish beneath. Antennae bronzy-brown, broadly annulated with white. Thorax shining dark brown. Abdomen and legs grey-fuscous. Forewings rather long, costa moderately arched, apex obtuse, termen rounded, oblique; shining brassy with cupreous reflections; *a large white oviform spot in middle near base; a broad white striga from dorsum at middle reaching half across wing; an irregular white blotch above tornus;* a streak of purplish-violet from beneath basal spot along fold to tornus, attenuated at extremities and interrupted at median fascia and before tornus; a similarly coloured but more obscure streak from above median fascia to tornal blotch: cilia grey, darker round apex. Hindwings and cilia grey.

Not closely related to any other *Orthenches;* perhaps nearest to *O. drosochalca* Meyr., but quite different in the arrangement of markings.

Invercargill. The type was taken in July, and another specimen was secured in February.

TINEIDAE.

Sagephora exsanguis n. sp.

♂. 10–12 mm. Head white, face ochreous. Palpi white, apical half of second joint brown. Antennae, thorax, and abdomen white. Forewings elongate, narrow, costa moderately arched, apex round-pointed, termen rounded, extremely oblique; *white; costa and dorsum broadly pale-brownish throughout reducing ground-colour to a median stripe;* apical half of dorsal stripe irregularly margined above with blackish; a few dark scales on costa near apex: cilia concolorous with wing-markings. Hindwings and cilia shining white.

Differs from the other members of the genus in its pale coloration.

A single specimen taken at Bluff in November, and a few secured by Mr. C. E. Clarke near Dunedin in October, November, and December.

MICROPTERYGIDAE.

Sabatinca barbarica n. sp.

♂. 10–11 mm. Head rather bright ochreous. Antennae pale ochreous, apical portion black. Thorax ochreous. Abdomen dark greyish-fuscous. Legs ochreous, tarsi annulated with black. Forewings ovate-lanceolate, costa moderately arched, apex acute, termen extremely oblique; *pale ochreous; a bright coppery suffusion along dorsum often segregated into one or more spots;* base of costa obscurely darker; an interrupted irregular coppery fascia from costa near base to tornus, sometimes including an almost black spot at middle; sometimes one or more coppery spots on costa at $\frac{1}{2}$; three coppery (sometimes blackish) spots on costa at apex, from which an irregular coppery fascia runs towards dorsum, connecting with first fascia above tornus; sometimes a blackish dot on termen at middle: cilia pale ochreous.

Near *S. caustica* Meyr., but larger and more vividly marked.

Seaward Bush (Invercargill). Eight examples taken amongst low herbage in the forest in December and January.

ART. X.—*Descriptions of New Zealand Lepidoptera.*

By E. MEYRICK, B.A., F.R.S.

Communicated by G. V. Hudson, F.E.S.

[*Read before the Wellington Philosophical Society, 12th December, 1917; received by Editors, 22nd December, 1917; issued separately, 24th May, 1918.*]

THE material for these notes was received from my esteemed correspondent Mr. G. V. Hudson.

PHYCITIDAE.

Delogenes n. gen.

Tongue developed. Antennae in ♂ shortly ciliated, slightly sinuate and thickened towards base of stalk, basal joint moderate. Labial palpi moderate, subascending, second joint considerably thickened with dense appressed scales, terminal joint very short, obtuse. Maxillary palpi imperceptible. Forewings with 4 and 5 stalked, 9 and 10 out of 8. Hindwings with cell not quite reaching middle; 3 and 4 stalked, 5 absent, 7 out of 6, anastomosing with 8.

This remarkable and interesting genus is a notable addition to the scanty local representation of the family.

Delogenes limodoxa n. sp.

♂. 24 mm. Head, palpi, and thorax grey suffusedly irrorated with whitish. Abdomen whitish-grey, anal tuft ochreous-whitish. Forewings very elongate-triangular, very narrow at base, costa almost straight, gently arched towards apex, apex obtuse, termen slightly rounded, oblique; fuscous, finely and suffusedly irrorated with white; lines dark brown sprinkled with blackish, first rather oblique, nearly straight, dilated towards costa, second

at $\frac{4}{5}$ parallel to termen, sharply angulated outwards in middle and inwards above this, marked with a series of short black dashes on veins, and followed by a whitish shade becoming white on costa and edged posteriorly with a series of small dark-fuscous marks; two cloudy brownish sometimes connected spots transversely placed on end of cell; a terminal series of cloudy dark-fuscous dots or marks: cilia light fuscous irrorated with white. Hindwings light grey: cilia whitish-grey.

Waitati (Clarke); two specimens. Superficially this suggests a *Scoparia*.

CARPOSINIDAE.

Carposina sarcanthes n. sp.

♂. 15 mm. Head white, with a few grey specks. Palpi whitish sprinkled with grey, basal half dark fuscous. Thorax grey with a curved white median bar, patagia white with some grey scales. Abdomen pale pinkish-ochreous. Forewings elongate, rather narrow, posteriorly somewhat dilated, costa gently arched, apex obtuse, termen straight, oblique; pale grey, irregularly mixed with white and somewhat sprinkled with dark fuscous; a semi-oval blackish blotch on base of costa; seven dots of blackish irroration on costa between this and apex; two small round grey spots edged beneath with blackish and circled with white beneath costa towards middle; a blackish-mixed tuft edged posteriorly with white in disc at $\frac{1}{3}$, one beneath middle of disc, and two on end of cell, discal area between these blackish-sprinkled and without whitish scales; an irregular subterminal series of blackish dots edged posteriorly with white: cilia pale grey irrorated with white. Hindwings whitish-grey, basal half suffused with pale pinkish-ochreous: cilia grey-whitish.

Wellington (Hudson); one specimen. Specially characterized by the pale pinkish-ochreous basal half of hindwings.

GELECHIADAE.

Epithectis Meyr.

Basal joint of antennae without pecten. Labial palpi with second joint slightly rough beneath, terminal joint nearly as long as second. Forewings with 7 and 8 out of 6. Hindwings nearly 1, trapezoidal, apex pointed, produced, termen sinuate; 3 and 4 connate, 5 somewhat approximated, 6 and 7 stalked.

A widely distributed genus, not previously known from New Zealand.

Epithectis zophochalca n. sp.

♂. 9 mm. Head shining bronzy-metallic. Palpi whitish-bronzy, second joint hardly rough beneath, anterior edge of terminal joint dark fuscous. Thorax purplish-bronzy-fuscous. Abdomen dark fuscous. Forewings lanceolate; glossy rather dark bronzy-fuscous; stigmata blackish, plical obliquely before first discal; small cloudy whitish spots on costa before $\frac{3}{4}$ and on tornus slightly anterior to this, on one wing connected by a faint straight whitish shade: cilia fuscous, round apex with a dark-fuscous antemedian line. Hindwings with apex considerably produced; dark fuscous; a fine longitudinal hyaline line in disc: cilia fuscous.

Auckland, in January (Hudson); one specimen.

OECOPHORIDAE.

Borkhausenia thranias Meyr.

Two examples sent, taken at the Dun Mountain, Nelson, in January (Hudson); one of these is quite like the unique type specimen from

Whangarei (which has cilia of forewings yellow), but the other has the cilia of forewings light grey, giving a quite distinct aspect; as they were taken together, and are alike in all other respects, they are doubtless the same species, but it is an unusual form of variation.

Trachypepla photinella Meyr.

An example in good condition sent by Mr. Hudson shows a well-marked scale-tuft above dorsum of forewings at $\frac{1}{4}$ (rubbed in all examples previously seen), and therefore the species is referable to *Trachypepla*, and not to *Eulechria* as hitherto supposed.

TINEIDAE.

Endophthora pallacopis n. sp.

♂. 12 mm. Head white. Palpi white, externally dark fuscous. Thorax pinky-whitish sprinkled with fuscous (partly defaced). Abdomen light grey. Forewings narrowly elongate lanceolate; 7 and 8 stalked; pinky-whitish, with scattered light olive-brown scales; a slender blackish streak along costa from base to near $\frac{1}{3}$, edged beneath by a light olive-brownish streak; a black basal dot in middle, and one on lower edge of this streak towards apex; some scattered black scales along dorsum; a blackish mark on costa before middle, edged beneath by a light olive-brown spot connected anteriorly with a similar spot beneath it in disc by a transverse-linear black dot; a blackish mark on costa at $\frac{2}{3}$, with a light olive-brownish spot adjoining it beneath: an irregular light olive-brownish spot on tornus, and one resting on termen below middle; some black irroration along termen; two irregular blackish dots on costa near apex: cilia whitish, basal half suffused with light grey and slightly sprinkled with blackish. Hindwings light grey: cilia whitish-grey.

Wellington, in December (Hudson); one specimen.

MICROPTERYGIDAE.

Sabatinca eodora n. sp.

♂ ♀. 10 mm. Head, palpi, and thorax fulvous. Antennae ochreous, with a black band of three joints above middle and another of three or four joints beneath apex. Abdomen blackish-grey. Forewings suboblong, costa rather abruptly arched anteriorly, then nearly straight, slightly arched towards apex, apex obtuse, termen slightly rounded, rather strongly oblique; light rosy-pink, more or less sprinkled or suffused with grey except on basal third; basal third orange-fulvous, including a bright-yellow transverse blotch edged with a few black scales from costa at $\frac{1}{4}$; a yellow dot edged with black on dorsum before middle; a somewhat oblique bright-yellow fasciate blotch from middle of costa reaching half across wing, edged with a few black scales and margined with orange-fulvous continued as an orange-fulvous fascia to dorsum beyond middle, its anterior margin marked with a yellow black-edged dot below middle and a black mark on dorsum; an irregular narrow orange-fulvous fascia from $\frac{3}{4}$ of costa to tornus, partially edged with black scales, and marked with two or three small variable yellow dots; two small yellow anteriorly black-edged spots on costa towards apex and two on termen: cilia yellow barred with grey, base tinged with rosy. Hindwings deep purple, becoming dark grey anteriorly: cilia dark grey, on costa with two indistinct pale-yellowish bars.

Shedwood Forest, Tapawera, near Nelson, in January (Hudson); four specimens. A very elegant and distinct species.

ART. XI.—*Notes from Canterbury College Mountain Biological Station, Cass.*

NO. 6.—THE INSECT-LIFE.

By F. W. HILGENDORF, D.Sc.

[*Read before the Canterbury Philosophical Institute, 5th September, 1917; received by Editors, 31st December, 1917; issued separately, 24th May, 1918.*]

INTRODUCTION.

THE general descriptions which have been written of the physiography and plant-associations in the neighbourhood of the station are essential starting-places for, as well as stimulants to, more detailed study. With the object of preparing a similar paper on the insect-life near the station I made some collections during the summer and autumn of 1917, and arranged the specimens thus captured in a small museum case deposited at the station for reference by future students. The notes on the collection were at first intended to be purely systematic, but it was soon recognized that the insects were so noticeably a part of the landscape that they should be dealt with in the order of their occurrence rather in that of their zoological classification. Thus on tussock or in swamp or forest different associations of insects are found, and in the following pages these associations are described, and in some cases attempts are made to explain their relationships to their environment. Of course, in dealing with several orders of insects no attempt at a complete catalogue can be made even when only a small area is under consideration, and so these notes deal only with the species that from their size or numbers come readily under the observation of the student.

A. THE ENVIRONMENT.

The topography and physiography of the neighbourhood of the station are described by Chilton* and Speight†. The variation in land and water is such as to encourage a great diversity of insect-life. Within a radius of little more than a mile from the station there are a lake, a swamp, a sluggish stream, many rapid streams, a shingly river-bed, a stretch of open tussock country, open shrub-land, shrubby thicket, patches of forest, and areas of bare rock, with slopes of scree. Each topographic form is in general associated with a special kind of plant-covering, and this, of course, forms the dominant factor in the environment of the insect population. The plant-associations are described by Cockayne and Foweraker,‡ and such a description is essential as a basis for any attempt at detailing the modes of life of the insects.

The plant-life of the area is to a certain extent unaltered by the advent of man. The forest, the shrub-land, and the river-bed and rock plants are probably almost entirely primitive. Even the tussock-land has been altered but little, and the alteration that has occurred seems more in the direction of varying the proportions of the primitive plants than in their replacement by introduced species.

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* C. CHILTON, Notes from Canterbury College, Mountain Biological Station, No. 1' *Trans. N.Z. Inst.*, vol. 47, p. 331, 1915.

† R. SPEIGHT, *ibid.*, vol. 48, p. 145, 1916.

‡ L. COCKAYNE and C. E. FOWERAKER, *ibid.*, vol. 48, p. 166, 1916.

Hypochaeris radicata, however, is found all over the open country, and is freely visited by the small bee *Dasycolletes hirticeps*. *Trifolium minus*, too, which occurs in the gullies, is probably visited by some insect, as it sets seed freely, and the seeds have been germinated from sheep-dung. These are the only cases noted where change of vegetation may have influenced insect-habits.

In the animal world, however, or at least in the vertebrate world, the most profound changes have been made. Over practically the whole of the area the sheep reigns supreme, and the effect of its grazing upon certain flowers has doubtless been reflected on the insect population. With the sheep has been introduced *Oestrus ovis*, the sheep's nasal bot-fly, which lays its eggs in the sheep's nostrils, so that on hot days the persecuted beasts may be seen stamping their feet, tossing their heads, or standing huddled together with noses to the ground. Sheep's dung, too, must be fed upon by numerous maggots and beetles, and the animals that die have a marked effect upon the numbers of blow-flies that infest this and all similar localities. Except the sheep, the only mammal that could affect the vegetation is the hare, and of this only occasional specimens are seen. Bird-life is not at all plentiful, and has probably changed considerably as a result of human occupation. Of water-birds, the paradise duck (*Casarca variegata*) is the most common, flocks of twenty or thirty being frequently seen on Lake Sarah and in the swamps. Grey ducks (*Anas superciliosa*) and a very few black swans also occur on the lake. An odd pukeko (*Porphyrio melanonotus*) may be seen in the swamp, and an occasional shag (*Phalacrocorax carbo*) passes from stream to stream. The black-cap tern (*Sterna albistriata*) and the seagull (*Larus dominicus*) are rather common on the river-beds. Of native land-birds the grey warbler (*Pseudogerygone igata*) is the commonest in shrub-land and forest-skirt. The kea (*Nestor notabilis*) occurs in flocks of ten to twenty above the line of about 4,000 ft., and traces of its scratching for earth-boring insects are frequently seen. The banded dotterel (*Ochthodromus bicinctus*) is common on the river-beds, an occasional hawk (*Circus gouldi*) nests in the swamps, and very rarely a morepork (*Ninox novae-zealandiae*) may be heard from the patches of forest. Introduced birds are much more numerous. The skylark (*Alauda arvensis*) is found everywhere, and a nest with eggs was seen among the rocks at an elevation of nearly 5,000 ft. Skylarks are in this locality almost purely insectivorous, though in the agricultural districts poisoned grain scattered over a field of sprouting wheat kills more larks than sparrows. The house-sparrow (*Passer domesticus*) and starling (*Sturnus vulgaris*) build about the railway-station, but, while the sparrow keeps near the buildings, the starling may be seen a mile away on the rocks and the tussock-land. Thrushes (*Turdus musicus*), blackbirds (*T. merula*), red-polls (*Linota rufescens*), and, most of all, yellowhammers (*Emberiza citrinella*) have invaded the shrub-land, and doubtless exert a considerable effect on the insect-life.

It seems likely that birds were once much more numerous than they are at present. This opinion is based upon two facts: (1) The development of protective coloration among all orders of insects is very perfect, and seems much more elaborate than is necessary to escape the meagre army of enemies now present. Further, many insects are abandoning (or, it may be, had never acquired) the habits that would conduce to safety from bird-attack. *Crambus flexuosellus*, the common yellowy-white moth of the tussocks, is a familiar example. While stationary it is invisible, but it rises before the walker at every step, and its movement when disturbed

would soon lead to its extermination if there were a hungry insectivorous-bird population. The highly protectively coloured *Scoparia philerga* of the forest-glades is quite invisible as it sits at rest on the trunks of the beech-trees, but if one walks noisily forward the moth will fill the air in its fluttering hundreds. It is true that in both these cases the kind of noise demanded is not that associated with a bird-attack, and the short zigzag flight and quick settling may lead to escape from other dangers. Still, protective coloration and the crouching habit are nearly always associated, and in many insects at Cass that association does not exist. (2) The second fact indicating a more plentiful bird-life in the past is the great profusion of berries and drupes borne by the shrubs. The close connection between the presence of birds and the production of succulent fruits is denied by Guppy,* but his views do not appear to have received wide acceptance. The writer's view is that if there were no frugiverous animals, then the characteristic of producing brightly coloured, fleshy, and palatable fruits would not have been fixed in so high a degree as is commonly found, and that a large number of plants bearing such fruits is evidence of a large bird population. The suggestion that frugiverous birds would have no effect on the insect-life is of little weight, as the annual variation in the food of birds is not well known. The variation is probably considerable, as is indicated by the fact that so purely a grain-eating bird as the sparrow feeds its nestlings for about six weeks on nothing but insects. Of more importance is the suggestion that the birds probably visited certain districts only during the fruiting season of the plants they specially favoured, and at that time would almost entirely neglect insects as food.

Except the birds, the only native land vertebrate is the common lizard (*Lygosoma moco*), which is found not infrequently on the tussock. In the lakes and streams, however, fish, especially trout, are very common, and the introduction of trout must have made an enormous difference to the insect and probably to the bird population of the district. Hudson† has shown that the stomachs of 60 trout taken from various localities contained 4,804 Neuroptera, 662 other insects, and 28 other animals. At this rate the reduction of Neuroptera in our streams must be enormous, and, as these insects, while aquatic in their immature stages, are aerial when adult, insect-eating birds may also have suffered a reduction in food-supplies sufficient either to drive them from the neighbourhood or at least to compel them to take to other food. In either case the reaction upon the general insect-life of the district must have been very considerable, and it becomes obvious that the insects are, on the whole, living in an environment that is much changed since the advent of the white man.

Two important factors in the environment are dead sheep and white flowers, for these are correlated with the two most striking features of the insect-life—namely, blow-flies by day and moths by night. The two common blow-flies are *Calliphora quadrimaculata*, the well-known bluebottle, and *C. oceana*, which is somewhat smaller, and is covered with bright-yellow hairs below. Both these species occur in hundreds everywhere, and fill the air with their buzzing wherever a human being rests for a few minutes. When a sheep dies the blow-flies are attracted from near and far: each lays a hundred or more eggs upon it, and the resultant maggots are fully fed through their active life. But the thousands of flies thus

* H. B. GUPPY, *Observations of a Naturalist in the Pacific*, vol. 2, p. 99, 1906.
† G. V. HUDSON, *New Zealand Neuroptera*, West and Newman, London, 1904.

produced do not always find a dead sheep on which to lay their eggs, and therefore they are urgently attracted to any place where there is the faintest scent of animal matter. I have seen *C. quadrimaculata* so violently impelled to lay her eggs somewhere that she has done so on a bicycle-tire where it had just been pressed with a perspiring hand.

After nightfall the swarms of moths are as insistent as are the blow-flies by day. These night-flying honey-suckers are represented by about twenty species, and, as these were obtained chiefly round the lamp in the living-room of the station, definite search would probably double the number of species. Now, the day-flying honey-suckers number only eight species, and the disproportion in individuals is much greater. The entomophilous flowers of the neighbourhood, therefore, must depend chiefly upon night-flying insects, and the colours of their flowers should be most commonly white, or some pale tint, rather than the darker colours of red, blue, or deep yellow.

An examination was made of the list of plants near the station as given by Cockayne and Foweraker, and the colours of such of them as produce nectar were taken from Cheeseman's *Manual of the New Zealand Flora*. The examination showed that fifty-one native plants were described as having flowers either white, rosy white, or pale blue or white, while only sixteen were described as yellow, red, blue, or brown. Dr. Cockayne has pointed out to me the undeniable fact that, to the human eye at least, white flowers are much more conspicuous even by day than those of any other colour, so that it would probably be quite incorrect to regard every white flower as cross-fertilized by night-flying insects. At the same time, given the nocturnal or crepuscular honey-suckers, it would obviously be advantageous for the plant to have white flowers: abundance of such flowers would encourage the multiplication of the insects that depend on them for their food; so that the large excess of plants bearing white or pale flowers is here regarded as an important factor in the character of the insect population.

B. The Insect-associations.

The above term has been used to indicate that, as the plants of the area are grouped into definite associations depending on environmental conditions, so the insects are grouped together according to their environment, of which, of course, the plant-covering is the most important factor. The insect-associations have been named more or less closely after the plant-associations, partly to avoid multiplication of names, and partly because the plant-covering is more conspicuous and forms the determining factor in the character of the insect-association. The range of species in an insect-association is, of course, not so clear-cut as in the plant-associations; for, while one may be able to say to a yard where tussock ends and swamp begins, the insects proper to one kind of environment may be found flying over the plants of another—as, for instance, when dragon-flies or sand-flies are found on the tussock. Again, insects that feed on the plants of one association may take shelter in another, as in the case of numerous moths which probably feed on the flowers of the shrub-land, but shelter by day in the forest, or may be attracted by night to a light on the tussock. The variety of plant-associations in close proximity to the station is a great advantage from most points of view, but in the present instance may lead to some errors in assigning certain insects to their proper associations.

1. *The Tussock Grass-land.*

Large numbers of yellowish-white moths rise from the tussocks at every step. These are chiefly *Crambus flexuosellus*, but *Scoparia salbulosella* is almost equally common. *Crambus simplex* and *C. ramosellus* also occur. These all have a wing-span of about 23 mm., and the *Scoparia* has pale-grey front wings. The metallic-blue butterfly *Chrysophanus boldenarum*, of 22 mm. wing-span, flutters about the open spaces a few inches from the ground, and sinks from sight as it folds its wings over its back and displays only their mottled-grey undersides. The large attractive butterfly *Argyrophenga antipodum* flies lazily or sports merrily, usually in pairs, a few feet from the ground. This insect displays one of our best examples of protective coloration adapted to a special environment. The expanse of the wings is 45 mm., and their upper surfaces as well as the lower surfaces of the front pair have a rich brown background with bold orange masses, picked out with black and white spots. The remaining surfaces—namely, the lower ones of the back wings—have a buff background with longitudinal bright-silver stripes. The insect is most conspicuous while on the wing, but as soon as it settles on a tussock, its invariable resting-place, it becomes quite invisible: it exposes the buff and silver surfaces of its wings, which harmonize with the leaves of the tussock to an almost incredible degree of exactness. Occasionally *Chrysophanus salustius*, a yellow and black butterfly of 27 mm. wing-spread, may be seen flying low down, especially near the shrub-land. and a few moths of the night may be accidentally disturbed. The blow-flies will always be hovering round, and the eye will be caught by the furtive flights of several other Diptera, usually protectively coloured. The repulsive bristly *Hystricia pachyprocta*, with a stout yellow body 15 mm. in length, and the somewhat smaller *Macquartia kumaraensis* and *M. subtilis*, often remain stationary long enough to permit of observation; while the darting *Limnia striata*, 7 mm. long, and with curiously mottled wings, will usually require a grab with the hand to effect its capture. Two smaller flies that will hardly be noticed may be captured in scores by walking along with a net held near the surface of the tussock. One of these is probably an undescribed species of *Trypeta*, and the other may be a representative of a new genus of the family Dexiidae. *Itamus varius*, a predatory fly, 17 mm. in length, is very common.

Among the Hymenoptera the attractive *Ichneumon solicitorius*, with a yellow and black parti-coloured body, 15 mm. long, is frequently seen. *Lissonota flavopicta*, 10 mm. in length, with an ovipositor as long again, also occurs, as well as two other ichneumons that have not so far been identified. The common native bee, *Dasycolletes hirticeps*, with its bright-golden hairs on thorax and legs, is commonly seen working among the flowers of the introduced *Hypochaeris radicata*, and probably assists in the spread of this weed, which is the commonest introduced plant on the tussock-land. It may be noted here, for as far as it bears on insect-life, that this plant opens its flowers only from 8.30 a.m. till 3.30 p.m. even on the longest and most sunshiny days of the year. Another bee, 9 mm. in length, black but with downy white hairs on the thorax, also occurs on the tussock, but has not so far been identified. Specimens of the Coleoptera are not common. Down on the ground our handsome metallic black and green *Trichosternus antarcticus*, up to 30 mm. long, may be seen hurrying along, and dead specimens may be found in scores or hundreds lying on the gravel between the railway-lines. As this beetle is incapable of flight, it is difficult to see how it manages to climb over the rails, or how, once having

got between them, it cannot get out again. Six specimens of a new and handsome species of *Mecodema*, bright shining black and 25 mm. in length, have also been taken crawling along among the tussocks, as well as a few specimens of the handsome *Nascio enysi*, 9 mm. long, black with four large yellow spots, and the less common *Aemona separata*, a large pale-yellowish-brown beetle, and the small black *Anchomenus feredayi*. On clayey banks among the tussock *Cicindela feredayi*, or a closely allied species, with an intricate yellow edging to its brownish-black elytra, darts in and out of its holes in the ground or takes short flights to elude capture.

The only Orthoptera noted are the common grasshopper, *Phaulacridium marginale*, which varies in colour from brown to green but always has a pair of white lines along the sides of the back of the thorax, and *Paprides australis*. Members of the other orders are not common. The cicada *Melampsalta nervosa* is more frequently heard than seen, and one of the Coccidae sometimes produces a striking appearance in the heart of the wild-spaniard (*Aciphylla squarrosa*). At first glance it appears as if a cup of flour had been emptied into the centre of the rosette of leaves, but on examination this is seen to be the waxy excretion of *Pseudococcus oamaruensis*, living specimens of which may be seen crawling among the mass of mealy powder. Anywhere near the swamps sand-flies are bound to occur, and an occasional dragon-fly may dart past.

Here also must be mentioned three introduced insects: the house-fly, which occurs sparingly indoors; the European earwig (*Forficula auricularia*), which is very common under boards, &c., lying round the railway-station buildings; and the sheep's nasal bot-fly (*Oestrus ovis*), which lays its eggs in the sheep's nostrils.

2. *The Lake and Swamp.*

In the shallow water near the edge of the lake the water-boatman (*Anisops*) occurs freely, darting up to the surface for air and down again to feed. In the same position the larvae and nymphs of most of the dragon-flies may be found, but they are so effectively protected by their transparency or greenish tints that they easily escape observation despite their length of 20 mm. or over. In the swamp round the lake and lower down the Grassmere Stream the dragon-flies are the most conspicuous insects. The largest is *Uropetala carovei*, which is 8 cm. or 9 cm. in length and 10 cm. or 11 cm. in wing-span. As well as being the largest it is the rarest of the dragon-flies, perhaps because its larva and nymph, which is found in Lake Sarah up to 4·5 cm. long, must afford such suitable food for the large trout which abound there. This dragon-fly shows in perfection the habit of many of the species in frequenting a favourite spot over which it ranges in its hawking flights. Besides the swamps it is common on the rock-faces that border the Waimakariri. Next in size and frequency is *Somatochlora smithii*, 4·5 cm. in length and 6 cm. in wing-span. The thorax is metallic green, and in the male the proximal segments of the abdomen are of reduced diameter. This species dives into the water of smooth pools and picks off the surface floating larvae of certain gnats. It appears to wet only its head, and may make ten or twenty dives in a minute. *Lestes colensonis*, 4 cm. in length and with a very slender abdomen, is the commonest species, and the females seem to preponderate largely. Finally comes *Xanthagrion zealandicum*, 2·7 cm. in length, with an abdomen that is often reddish in the male and blue in the female.

Of the Diptera by far the commonest is the gnat *Chironomus*, about 7 mm. long, which frequently occurs in such numbers that its swarms appear at a distance like columns of smoke. Various crane-flies are also common, the most noticeable being *Tipula novarae*, 25 mm. in length, and with a wing-span of 45 mm. *T. obscuripennis* and an unnamed species also occur. One particular moth, *Xanthorhoe clarata*, a handsome species with wavy lines of brown and yellow on the forewings, which are about 40 mm. across, has been captured only on the swamp-land, but its real home is probably in the adjacent shrubs.

3. *The River-bed.*

In the waters of the rapidly running streams are to be found the larvae of the sand-fly (*Simulium australense*) hanging to or crawling on the upper surface of the submerged stones, and there also occur underneath the stones larvae of the several Neuroptera to be mentioned immediately. These together with the sand-flies hover over the stony or shrubby banks of the river, or drift on to the tussock. The commonest species is *Coloburiscus humeralis*, with a wing-span of 30 mm., and three tails, the two outer of which are considerably longer than the body. *Pseudoeconesus mimus* occurs near streams in the forest. *Pseudonema obsoleta*, whose larva inhabits bored-out twigs in the forest-streams, is strongly attracted to light, and sometimes occurs in hundreds on the windows of the station. Its wing-expanse is about 35 mm. to 40 mm., and its antennae reach a length of 45 mm., being about three times as long as its body. *Hydriobiosis umbripennis*, whose larva is remarkable in that it does not live in any kind of case, occurs commonly. It has a wing-expanse of 25 mm., the front wings being sooty brown and the back ones transparent. Besides these there are one or perhaps two species of Ephemeridae that have not been so far identified, and the larva, but not the adult, of some species of *Oniscigaster* has been captured.

The river-bed is rich in other insects besides the Neuroptera. The moth *Crambus xanthogrammus* is very plentiful, flitting from stone to stone when disturbed. Its wings have a span of 25 mm., and the forewings are marked with broad wavy lines of black and white. I have not seen this moth elsewhere than on the river-bed, and regard it as very characteristic of this association. Several striking flies also occur, chiefly *Anabarhynchus innotatus*, with its bluish-grey body 14 mm. in length; *Calcager apertum*, of almost equal size; and the small *Trypeta* mentioned before as occurring on the tussock. At least one large but unidentified bee occurs on the river-bed, but nowhere else, so that, on the whole, this is a very distinct association, and a very numerous one considering the limited number of apparent food plants.

4. *The Shrub-land.*

The insects of this association are much fewer in number than would have been expected—unless, indeed, species more easily captured elsewhere in reality belong to the shrub. Among the beetles the green manuka-beetle (*Pyronota festiva*) is sometimes common, but remains unseen unless it is found away from its natural background. The rarer *P. sobrina*, with its bronze elytra, may also be found. Clay banks in the open spaces swarm with the active *Cicindela tuberculata;* and the yellow-spotted black lady-bird, *Vedalia cardinalis*, occurs rarely. The same clay open spaces are frequented by great numbers of the hymenopterous *Dasycolletes purpureus*,

and flitting among these may be seen the slender *Gasteruption flavipes*, a black wasp-like insect 10 mm. in length. A single specimen of stick-insect, probably an immature *Clitarchus*, has been found; and these, with an unidentified bug, comprise the total of the insects readily noted on the shrub-land. There are, however, some twenty moths that have been captured by night on the tussock or by day in the forest, and it is probable that the feeding-ground of these insects is the shrub-land, where nectar-producing plants are commonest.

5. *The Forest.*

Although twenty-four species of plants are recorded as growing in the forest, thirteen of these grow only along the stream-banks, and, of the remaining nine, one outnumbers all the others together by thousands to one. This plant is the *Nothofagus cliffortioides*, the mountain-beech. It is the only plant that reaches tree-size, the others forming merely a very scattered undergrowth, which in many places is quite absent. From this description it would be expected that the insect-life would be scanty. Moths, however, are very numerous, especially in individuals. As mentioned before, the noisy advance of an intruder will fill the air with hundreds of darting, fluttering specimens of *Scoparia philerga*, of 25 mm. wing-span. The front wings are mottled grey, and when closed have a conspicuous pale band across their basal third.

Hydriomena deltoidata, of 35 mm. wing-span, an attractive moth with brown front wings crossed by wavy bands of white, and *Asaphodes megaspilata*, a reddish-yellow moth of 23 mm. wing-span, are very plentiful in the clear spaces within the forest, while round its edge one disturbs thousands of specimens of *Palaeomicra zonodoxa*, a small yellow moth with fringed wings that glance like gold in the sun as the insect darts from shelter to shelter.

All these, however, are probably shrub-land insects hiding in the forest shades by day, for the patches of forest are so small that no part of them is far away from the surrounding shrub-lands.

The case-moth, *Oeceticus omnivorus*, however, belongs to the forest, as is shown by the beech-leaves woven in to conceal its leathery case.

Approaching the forest-streams one finds the river-bed insects becoming common, the sand-flies, caddis-flies, and Ephemeridae, with *Pseudonema obsoleta* specially numerous, as would be expected from the twig-boring habits of its larva. A single Dipteron, *Mycetophila fagi*, also occurs in large numbers.

6. *The Rocks.*

Large areas of bare rock occur at and above the 4,000 ft. line near the station, but none of these was visited except the small exposures on the Sugarloaf (4,475 ft.). Here the most conspicuous insect is a fat stone-grey grasshopper, up to 25 mm. in length. It is very distinct from all the species of which record has been found. The only other insects inhabiting these rocky spaces and not found on the tussock near by are three moths of about 25 mm. wing-span. *Notoreas ferox* has dark-brown almost black upper sides to its front wings, while the other wing surfaces are bright-orange with black wavy lines. *Dasyuris anceps* and an unidentifiable *Harmologa* are pale yellow on the wing-surfaces concealed when at rest, but stone-grey or brown on the surface exposed on alighting.

C. List of Insects captured near the Station.

T = tussock; S = swamp; L = lake; R = river-bed; Sh = shrub-land; F = forest; R = rock. ? means that owing to conditions of capture it is not certain that the insect really belongs to the association to which it is ascribed.

Order Hymenoptera.

Dasycolletes hirticeps. T.
D. purpureus. Sh.
Prosopis sp. T.
P. sp. R.
Ichneumon solicitorius. T.
I. spp. T.
Lissonota flavopicta. T.
Gasteruption flavipes. Sh.

Order Coleoptera.

Cicindela feredayi (?). T.
C. tuberculata. Sh.
Mecodema n. sp. T.
Trichosternus antarcticus. T.
Anchomenus feredayi. T.
Pyronota festiva. Sh.
P. sobrina. Sh.
Aemona separata. T.
Nascio enysi. T.
Vedalia cardinalis. Sh.

Order Lepidoptera.

Nyctemera annolata. T.
Orthosia comma. T. (?)
Physetica coerulea. T. (?)
Leucania propria. T. (?)
L. nullifera. T. (?)
L. acontistis. T. (?)
Melanchra compositis. T. (?)
M. insignis. T. (?)
Agrotis ypsilon. T. (?)
Hydriomena deltoidata. F. T. (?)
Venusia undosata. T. (?)
Asaphodes megaspilata. F. (?)
Xanthorhoe rosearia. T. (?)
X. clarata. S. (?)
Dasyurus anceps. R.
Notoreas ferox. R.
Sestra humeraria. T. (?)
Argyrophenga antipodum. T.
Chrysophanus salustius. T.
C. boldenarum. T.
Scoparia philerga. F.
S. salbulosella. T.
Platiptilia falcatilis. T.
Crambus flexuosellus. T.
C. simplex. T.
C. ramosellus. T.
C. xanthogrammus. R.
Oeceticus omnivorus. F.
Harmologa sp. R.
Proteodes carnifex. T. (?)
Palaeomicra zonodoxa. F. (?)
Porina umbraculata. T. (?)

Order Diptera.

Mycetophilus fagi. F.
Chironomus zealandicus. S.
Tipula obscuripennis. S.
T. novarae. S.
T. sp. S.
Simulium australense. S.
Ryphus sp. T.
Anabarhynchus innotatus. R.
Itamus varius. T.
Limnia striata. T.
Trypeta sp. T. R.
Macquartia kumaraensis. T.
M. subtilis. T.
M. sp. R.
Hystricia pachyprocta. T.
Calcager apertum. T.
Species of fam. Dexiidae. T.
Calliphora quadrimaculata. T.
C. oceana. T.
Musca domestica. T.
Oestrus ovis. T.

Order Hemiptera.

Anisops wakefieldi. L.
Melampsalta nervosa. T. S.
Pseudococcus oamaruensis. T.

Order NEUROPTERA.

Uropetala carovei. S.
Somatochlora smithii. S.
Lestes colensonis. S.
Xanthagrion zealandicum. S.
Coloburiscus humeralis. R.
Oniscigaster sp. R.
Pseudoeconesus mimus. R.
Pseudonema obsoleta. R. F.
Hydrobiosis umbripennis. R.

Order ORTHOPTERA.

Clitarchus sp. S.
Phaulacridium marginale. T.
Paprides australis. T.
Species of Acridiidae. R.
Forficula auriculata. T.

ART. XII.—*On a Partially White Form of* Puffinus griseus *Gmelin.*

By D. L. POPPELWELL.

[*Read before the Otago Institute, 12th June, 1917; received by Editors, 22nd December, 1917: issued separately, 24th May, 1918.*]

ALBINISM of a complete or partial nature has several times been reported in connection with New Zealand birds, but the cases of its occurrence are not so frequent but that they should be recorded. On the 26th April, 1916, when returning from a trip to Stewart Island, I was shown by Mr. John Smith, of the Bluff, a live specimen of a mutton-bird (*Puffinus griseus*) which showed partial albinism. This interesting specimen was captured by Mr. Smith on Piko-mamaku-iti, the most northerly of the Titi Islands, where Mr. Smith was mutton-birding. The bird was a young one, and was caught in a nest. It was almost fully fledged. The head, neck, and upper part of the breast of this interesting specimen were pure white, back and upper part of the wings partly black, abdomen brown, the tail white. The bird, as mentioned above, was a young one, and in parts still had the down attached. Its beak was of a pinkish white, its legs pink, and its eye greenish. I examined the bird closely, and took certain measurements and other particulars, which were as follows:—

	Inches.
Length from tip of beak to butt of tail	13·50
Length of side of beak	2·25
Length of beak from tip to nostrils	1·25
Length of wing from flexure	12·00
Total length of wing	19·00
Total spread of wings	42·50
Length of tarsus	2·25
Length of middle toe	2·75
Number of feathers in tail, fourteen.	

NOTE.—The above measurements are, I believe, correct; but, as the bird was alive and resented handling, some difficulty was experienced in

getting some of the measurements exactly. The normal colour of *P. griseus* is, of course, a sooty brown, the bill horn-colour, and the legs and feet brown. Mr. Smith informed me that partially white mutton-birds are not uncommon, but are yet sufficiently rare as to make a specimen of special interest even to the birders. I had hoped that this specimen would be sent to the Otago Museum, but I understand it has been disposed of privately.

As the normal number of feathers in the tail in *Puffinus* is only twelve, may not the above specimen be a hybrid between *Puffinus griseus* and some closely allied genus, such as *Priocella*, which has fourteen feathers in its tail? Of course, I may have made a mistake in identification, but the measurements closely accord with *P. griseus*. We know so little of the habits and life-histories of many of our sea-birds that some such explanation of these abnormal forms seems reasonable. The slight difference in the measurements with those laid down for *P. griseus* may be thus accounted for.

On the 14th June, 1916, I had an interview with Mrs. Sidney Ladbrook, of Mataura, who had just then returned from a birding expedition to Evening Island, off South Cape. She informed me that her party had found a pure-white mutton-bird on the island mentioned, but it was turned loose again. It seems that according to Maori superstition it is an evil omen to catch one of these rare specimens, portending death in the family of the captor. Mrs. Ladbrook informed me also that such a specimen is called a "jimmy bird" if it has white or pink eyes, but if the eyes are black it is known as a "queen bird" and the portent is less serious. The specimen which was caught on the trip just then completed was a pinkish white, but had black eyes. My informant says that these aberrant forms are sometimes found about the same spot in successive years. This latter statement receives corroboration from Mr. J. Bragg, of Half-moon Bay (see p. 38, Cockayne's *Report on a Botanical Survey of Stewart Island*, Parliamentary Paper C.–12, 1909: Government Printer).

POSTSCRIPT.

Since the above article was written a curious coincidence has occurred which will probably serve to intensify the southern Maori superstition concerning the danger of interfering with a white mutton-bird. The bird referred to by Mrs. Ladbrook was, I understand, caught by her husband. During the birding season of 1917 Mr. and Mrs. Ladbrook went to the same island again, and during a storm two children—a daughter and a niece—whom they had taken with them were washed off the rocks and not seen again. Mrs. Ladbrook informed me that some fear of the result was expressed by the Maoris when the bird was caught. The belief is that the calamity will occur within a year, and in this instance has strangely proved quite accurate.

Art. XIII.—*Notes of a Botanical Visit to Hollyford Valley and Martin's Bay, with a List of Indigenous Plants.*

By D. L. Poppelwell and W. A. Thomson.

[*Read before the Otago Institute, 12th June, 1917; received by Editors, 22nd December, 1917; issued separately, 24th May, 1918.*]

During the Christmas holidays of 1916–17 we, in company with some others, paid a visit to Martin's Bay, via the Hollyford Valley. We spent in all about ten days in the locality, examining the vegetation. Owing to lack of time and the difficult nature of the country, we were unable to climb any of the mountains, and consequently our notes relate only to the forest vegetation of Hollyford Valley and that of Martin's Bay itself. No list of the plants of these areas seems to have yet been published, so we append particulars of those seen by us, with some notes as to the ecological conditions and the forest vegetation.

Topography and Climate.

The Hollyford Valley from the point at which we entered it to the sea at Martin's Bay is about forty miles long. For over twenty miles of this distance it runs almost due north, and is bounded on the west by the Darran Range, which consists of very high and precipitous mountains, varying from 7,000 ft. to 9,000 ft. The principal peaks are Mount Christina (8,675 ft.) and Mount Tutoko (9,042 ft.). On the east side the mountains range from 4,000 ft. to 6,000 ft. in height. The valley is a narrow one, varying from less than a quarter of a mile to about two miles in width. The lower part trends more to the west, and consists of Lake McKerrow, twelve miles long, and a strip of three miles of level land to the sea. The mountains become much lower as the sea is approached. There is little doubt that this valley is subject to a very large rainfall, as is most of the western side of the South Island. The river is increased during its course by many snow-fed streams, which in the spring must be raging torrents. The Pyke River, which drains Lake Alabaster, is the largest of these streams, and is sufficiently deep to require horses to swim even when quite low, as it was at the time of our visit. We do not think this valley is subject to much frost in winter, and can vouch for the fact of great heat in summer. Our party did not experience a single shower during its visit, and from observations taken with the thermometer the shade temperature for several days exceeded 80° F. Where the track meets the valley below Howden Saddle the height above sea-level is between 500 ft. and 600 ft. The fall of the Hollyford River will therefore average about 15 ft. to the mile, although it is much greater in the upper part, as the last fifteen miles (including Lake McKerrow) is tidal.

Ecological Conditions.

The narrow valley, hemmed in by high mountains, and the high rainfall make the atmosphere warm and humid, and it consequently affords ideal conditions for plant-life. The soil mostly consists of detritus from the mountains, mixed with decaying vegetable matter, and is therefore rich and suitable for rank and rapid growth. The hanging mosses on all the tree-trunks and branches attest the high degree of atmospheric moisture.

The hillsides are very steep, and give ample facilities for the growth of both sun- and shade-loving plants. The bush-line ascends to about 2,800 ft. or 3,000 ft. The trees throughout the valley are very high and have fairly close tops, but the high rainfall helps the formation of a stronger undergrowth than is usual in beech forests.

THE FOREST ASSOCIATION.

Round about Lake Howden the forest is almost entirely a *Nothofagus* one, but an immediate change is noticeable as soon as the descent to the Hollyford is commenced. The principal beech-trees are *Nothofagus Menziesii* and *N. Solanderi*, although *N. fusca* is found in patches and *N. Blairii* is also present. Gradually the forest changes as the valley is descended, until the taxads *Dacrydium cupressinum, Podocarpus spicatus*, and *P. ferrugineus* form a large part of the vegetation. *P. Hallii* and *P. dacrydioides* are also found, but do not appear to be anywhere very plentiful in the valley. The undergrowth consists of a second tier of smaller trees, the association being principally *Pittosporum Colensoi, Nothopanax Edgerleyi, Carpodetus serratus, Metrosideros lucida* (not abundant), *Weinmannia racemosa* (comparatively rare), and *Griselinia littoralis*, with a fair sprinkling of the fern-trees *Hemitelia Smithii* and *Dicksonia fibrosa*, and a considerable growth of *Coprosma* scrub and ferns. The islands in the river are usually covered with *Coriaria ruscifolia, Cordyline australis*, and *Arundo conspicua*, while *Pratia angulata* and *Helichrysum bellidioides* cover the open spaces.

SUMMARY.

Perhaps the most interesting of our "finds" are *Metrosideros florida* Smith, and *M. scandens* Sol. *Freycinetia Banksii* A. Cunn. was common at both Martin's Bay and Lake Alabaster. *Wahlenbergia congesta* N. E. Brown was noted at Martin's Bay, which adds to the few known habitats of the species. The locality where found and relative abundance of the species are mentioned in the list. The total number of species noted was 226, belonging to 129 genera and 56 families.

LIST OF INDIGENOUS PLANTS.

PTERIDOPHYTA.

HYMENOPHYLLACEAE.

Trichomanes reniforme Forst. f. Forest; not uncommon.
—— *venosum* R. Br. Forest; rare.
Hymenophyllum sanguinolentum (Forst. f.) Sw. Tree-trunks.
—— *dilatatum* (Forst. f.) Sw. Not very common.
—— *ferrugineum* Colla. Fairly common.
—— *tunbridgense* (L.) Sm. On tree-trunks.
—— *demissum* (Forst. f.) Sw. Not uncommon.
—— *flabellatum* Labill. Not plentiful.

CYATHEACEAE.

Cyathea medullaris (Forst. f.) Sw. Martin's Bay; somewhat rare.
Hemitelia Smithii (Hook. f.) Hook Throughout
Alsophila Colensoi Hook. f. Not uncommon.
Dicksonia fibrosa Col. Not plentiful.
Leptolepia novae-zelandiae (Col.) Kuhn. Head of Hollyford Valley.

Polypodiaceae.

Polystichum hispidum (Sw.) J. Sm. Throughout.
—— *vestitum* (Forst. f.) Presl. Throughout.
Lindsaya viridis Col. Rare.
Asplenium adiantoides (L.) C. Chr. Near Mid Hut.
—— *bulbiferum* Forst. f. Common throughout.
—— *flaccidum* Forst. f. Common on trees.
Blechnum Patersoni (R. Br.) Mett. Fairly plentiful.
—— *discolor* (Forst. f.) Keys. Dry open spaces.
—— *vulcanicum* (Bl.) Kuhn. Epiphytic on rocky cliffs.
—— *lanceolatum* (R. Br.) Sturm. Steep banks.
—— *penna marina* (Poir.) Kuhn. Plentiful throughout.
—— *capense* (L.) Schlecht. Abundant.
—— *fluviatile* (R. Br.) Lowe. Not uncommon.
Hypolepis tenuifolia (Forst. f.) Bernh. Open spaces.
Adiantum affine Willd. Hidden falls, rocks.
Histiopteris incisa (Thbg.) J. Sm. Not abundant.
Pteridium esculentum (Forst. f.) Cockayne. Open places only.
Polypodium Billardieri (Willd.) C. Chr. Epiphytic on tree-trunks.
—— *gramitidis* R. Br. Epiphytic on tree-trunks.
—— *diversifolium* Willd. Climbing on tree-trunks.
Dryopteris pennigera Forst. f. Not uncommon.
Cyclophorus serpens (Forst f.) C. Chr. Climbing on trees.

Gleicheniaceae.

Gleichenia dicarpa R. Br. Swampy places.

Osmundaceae.

Leptopteris hymenophylloides (A. Rich.) Presl. Fairly common.
—— *superba* (Col.) Presl. Fairly abundant.

Ophioglossiaceae.

Botrychium ternatum Sw. Martin's Bay only.

Lycopodiaceae.

Lycopodium scariosum Forst. f. Not uncommon.
—— *volubile* Forst. f. Fairly common.
—— *Billardieri* Spring. Rare.
Tmesipteris tannensis Bernh. Not common; tree-trunks only.

SPERMOPHYTA.

Taxaceae.

Podocarpus Hallii T. Kirk. Not plentiful.
—— *nivalis* Hook. f. Only at high levels.
—— *ferrugineus* Don. Common.
—— *spicatus* R. Br. Plentiful.
—— *dacrydioides* A. Rich. Throughout.
Dacrydium cupressinum Sol. Fairly abundant throughout.
—— *intermedium* T. Kirk. Only near Martin's Bay.
—— *Colensoi* Hook. Martin's Bay only.
Phyllocladus alpinus Hook. f. Not uncommon.

POTAMOGETONACEAE.

Potamogeton Cheesmanii A. Benn. In ponds, &c.

SCHEUZERIACEAE.

Triglochin striata Ruiz. & Pav. var. *filifolia* (Sieb.) Buchen. Wet places, Martin's Bay.

GRAMINEAE.

Microlaena avenacea (Raoul) Hook. f. Common throughout.
Danthonia semiannularis R. Br. var. *setifolia* Hook. f. Rare: Hidden Falls.
—— *pilosa* R. Br. Head of Lake McKerrow.
—— *Cunninghamii* Hook. f. Not abundant.
Arundo conspicua Forst. f. Abundant on islands, &c.
Poa Colensoi Hook. f. Cliff-faces.
Festuca littoralis Labill. Sand-dunes.

PANDANACEAE.

Freycinetia Banksii A. Cunn. Abundant on creek-banks and at Martin's Bay and Lake Alabaster.

CYPERACEAE.

Scirpus inundatus (R. Br.) Poir. Swampy places, Martin's Bay.
—— *nodosus* (R. Br.) Rottb. Brackish water.
—— *frondosus* Banks & Sol. Sand-dunes.
Carpha alpina R. Br. Dry heath, Martin's Bay.
Gahnia procera Forst. Damp places.
—— *xanthocarpa* Hook. f. (?). Martin's Bay only.
Uncinia uncinata (L. f.) Küken. Common in forest.
Carex ternaria Forst. f. Damp places.
—— *lucida* Boott. On bush tracks, damp ground.
—— *pumila* Thbg. Damp sand.
Leptocarpus simplex A. Rich. Salt marshes.

JUNCACEAE.

Juncus polyanthemos Buchen. Damp places.

LILIACEAE.

Rhipogonum scandens Forst. Not abundant.
Enargea parviflora (Banks & Sol.) Hook. Fairly common.
Cordyline australis (Forst. f.) Hook. In Hollyford Valley.
—— *indivisa* Steud. Rare; near Howden Saddle.
Astelia nervosa Banks & Sol. Very abundant.
—— *montana* (T. Kirk) Cockayne. Dry places.
Dianella intermedia Endl. Lake McKerrow.
Phormium tenax Forst. River-bank.
—— *Cookianum* Le Jolis. Creek-banks, cliffs, &c.; common.

IRIDACEAE.

Libertia pulchella Spreng. Near Howden Saddle only.
—— *ixioides* Spreng. Dry places in forest.

Orchidaceae.

Dendrobium Cunninghamii Lindl. Tolerably common.
Earina mucronata Lindl. Epiphytic on tree-trunks.
—— *autumnalis* (Forst. f.) Hook. Epiphytic; not common.
Pterostylis Banksii R. Br. In damp forest.
Thelymitra longifolia Forst. Martin's Bay.
Corysanthes macrantha Hook. f. Damp banks, &c.
—— *oblonga* Hook. f. Forest-floor.
Gastrodia Cunninghamii Hook. f. Beech forest.
Bulbophyllum pygmaeum Lindl. Rocks, Martin's Bay.

Chloranthaceae.

Ascarina lucida Hook. f. Fairly plentiful; Martin's Bay.

Monimiaceae.

Hedycarya arborea Forst. Hollyford Valley and Martin's Bay; common.

Fagaceae.

Nothofagus fusca (Hook. f.) Oerst. Common.
—— *Menziesii* (Hook. f.) Oerst. Common.
—— *Solanderi* (Hook. f.) Oerst. Common.
—— *cliffortioides* (Hook. f.) Oerst. At higher altitudes.
—— *Blairii* (T. Kirk) Diels. Not common.

Urticaceae.

Urtica incisa Poir. Common in forest.
—— *ferox* Forst. Forest tracks; plentiful.

Loranthaceae.

Loranthus micranthus Hook. f. Martin's Bay
Elytranthe Colensoi (Hook. f.) Engl. Common on beech-trees.
—— *tetrapetalus* (Forst. f.) Engl. Common on *Fagus;* also found on *Griselinia.*
—— *flavida* (Hook. f.) Engl. Comparatively rare.

Polygoniaceae.

Rumex neglectus Kirk. Martin's Bay.
—— *flexuosus* Sol. Martin's Bay.
Muehlenbeckia australis (A. Cunn.) Meissn. Not abundant.
—— *complexa* (A. Cunn.) Meissn. Fairly common.
—— *axillaris* Walp. Rare.

Caryophyllaceae.

Stellaria parviflora Banks & Sol. Open tracks, &c.
Colobanthus acicularis Hook. f. Rocks and dry places.

Ranunculaceae.

Clematis indivisa Willd. Rare.
Ranunculus hirtus Banks & Sol. Not uncommon.
—— *rivularis* Banks & Sol. Martin's Bay.
—— *lappaceus* Sm. Open spaces, Martin's Bay.

MAGNOLIACEAE.

Drimys colorata Raoul. Not common.

CRUCIFERAE.

Cardamine heterophylla (Forst. f.) O. E. Schultz var. Forest tracks.

SAXIFRAGACEAE.

Carpodetus serratus Forst. Fairly plentiful.

PITTOSPORACEAE.

Pittosporum Colensoi Hook. f. var. Scattered throughout.

CUNONIACEAE.

Weinmannia racemosa L. f. Comparatively rare.

ROSACEAE.

Rubus australis Forst. f. Throughout.
—— *cissoides* A. Cunn. Not plentiful.
—— *subpauperatus* Cockayne. Not uncommon.
Potentilla anserina (L.) var. *anserinoides* (Raoul) T. Kirk. Damp places.
Acaena novae-zelandiae Kirk. Throughout.
—— *Sanguisorbae* Vahl. Common.
—— *microphylla* Hook. f. On tracks, &c.

GERANIACEAE.

Geranium microphyllum Hook. f. Near Martin's Bay.
—— *sessiliflorum* Cav. var. Sand-hills.
Oxalis magellanica Forst. Near Lake McKerrow.

OLACINACEAE.

Pennantia corymbosa Forst. Not plentiful.

EUPHORBIACEAE.

Euphorbia glauca Forst. f. Sand-dunes only.

CORIARIACEAE.

Coriaria ruscifolia L. var. Abundant and of great size.
—— *thymifolia* Humb. & Bonp. var. Fairly plentiful.
—— *angustissima* Hook. f. Not common.

LEGUMINOSAE.

Sophora tetraptera J. Mull. var. Lake McKerrow and Martin's Bay.
Carmichaelia flagelliformis Col. (?). Martin's Bay.

ELAEOCARPACEAE.

Aristotelia racemosa (A. Cunn.) Hook. f. Not abundant.
—— *Colensoi* Hook. f. Rare.
—— *fruticosa* Hook. f. Common.
Elaeocarpus Hookerianus Raoul. Comparatively rare.

Malvaceae.

Hoheria populnea A. Cunn. var. Pyke River.
Gaya Lyallii Baker. River-valleys.

Violaceae.

Viola Cunninghamii Hook. f. Not uncommon.
—— *filicaulis* Hook. f. Head of Hollyford Valley; rare.
—— —— var. *hydrocotyloides* (J. B. Armstg.) T. Kirk. Damp tracks.
Melicytus ramiflorus Forst. Common throughout.

Thymelaeaceae.

Pimelea Lyallii Hook. f. Sand-hills, Martin's Bay.

Myrtaceae.

Leptospermum scoparium Forst. Martin's Bay; not plentiful.
Metrosideros lucida Forst. f. Growing throughout, but local.
—— *hypericifolia* A. Cunn. Lower Hollyford.
—— *florida* Sm. Martin's Bay.
—— *scandens* Sol. Forest, Martin's Bay.
Myrtus pedunculata Hook. f. Common.

Onagraceae.

Epilobium rotundifolium A. Rich. Bush tracks.
linnaeoides Hook. f. Open spaces.
—— *melanocaulon* Hook. f. Creek-beds.
—— *nummularifolium* A. Cunn. var. *minimum* T. Kirk. Forest.
Fuchsia excorticata L. f. Not uncommon.
—— *Colensoi* Hook. f. Rare.

Halorrhagaceae.

Halorrhagis erecta (Murr.) Schindler. Sand-hills.
Gunnera albocarpa (T. Kirk) Cockayne. Damp places.

Araliaceae.

Nothopanax simplex (Forst.) Seem. Throughout.
—— *Edgerleyi* (Hook. f.) Seem. Throughout.
—— *Colensoi* (Hook. f.) Not plentiful.
—— *linearis* (Hook. f.) Harms. Near Howden Pass.
Pseudopanax crassifolium (Sol.) C. Koch var. *unifoliatum* T. Kirk. Not common.
Schefflera digitata Forst. Damp situations; fairly common.

Umbelliferae.

Hydrocotyle novae-zealandiae DC. Damp places.
Apium prostratum Labill. Near sand-hills.
—— *filiforme* (A. Rich.) Hook. Not uncommon.
Anisotome intermedia Hook. f. Rocks and creek-banks, Martin's Bay.

Cornaceae.

Griselinia littoralis Raoul. Not uncommon.
—— *lucida* Forst. Martin's Bay; not uncommon.

Ericaceae.

Gaultheria antipoda Forst. f. var. *erecta* Cheesem. Near Martin's Bay.

EPACRIDACEAE.

Styphelia acerosa Sol. Martin's Bay and Howden Saddle.
—— *Fraseri* (A. Cunn.) F. Muell. Martin's Bay.
Archeria Traversii Hook. f. Rare.
Dracophyllum longifolium (Forst. f.) R. Br. Not plentiful.

MYRSINACEAE.

Suttonia divaricata (A. Cunn.) Hook. f. Throughout.
Rapanea Urvillei (A. DC.) Mez. Rare.

CONVOLVULACEAE.

Calystegia tuguriorum (Forst. f.) R. Br. Rear of sand-hills.
—— *sepium* R. Br. (?). Near sand-hills.
—— *Soldanella* R. Br. On sand, Martin's Bay.

BORAGINACEAE.

Myosotis Lyallii Hook. f. (?). Bush tracks.

LABIATAE.

Mentha Cunninghamii Benth. Bush tracks.

SCROPHULARINACEAE.

Veronica salicifolia Forst. Common; creek-banks.
—— *subalpina* Cockayne. Creek-banks.
—— *leiophylla* Cheesem. (?). Hidden Falls; not common.
—— *Lyallii* Hook. f. Not uncommon.
—— *catarractae* Forst. Hidden Falls.
—— *buxifolia* Benth. Rare.
Ourisia caespitosa Hook. f. Near Howden Saddle.

RUBIACEAE.

Coprosma lucida Forst. Common throughout.
—— *parviflora* Hook. f. Fairly plentiful.
—— *acerosa* A. Cunn. var. *arenaria* T. Kirk. Dunes.
—— *foetidissima* Forst. Common in forest.
—— *rotundifolia* A. Cunn. In forest.
—— *areolata* Cheesem. In forest.
Nertera dichondraefolia (A. Cunn.) Hook. Common.
—— *depressa* Banks & Sol. Comparatively rare.

CAMPANULACEAE.

Pratia angulata (Forst. f.) Hook. f. Common.
—— —— variety with small leaf. In forest.
Wahlenbergia albomarginata Hook. Open spaces.
—— *congesta* (Cheesem.) N. E. Brown. Sand-hills, Martin's Bay.
Lobelia anceps L. Wet places, Martin's Bay.

COMPOSITAE.

Lagenophora pumila (Forst. f.) Cheesem. Not uncommon; Martin's Bay.
—— *petiolata* Hook. f. Plentiful.
Olearia arborescens (Forst. f.) Cockayne and Laing. Creek-banks.
—— *ilicifolia* Hook. f. Plentiful.
—— *avicenniaefolia* Hook. f. Common in places.
Celmisia longifolia Cass. var. Not plentiful.

Brachycome Sinclairii Hook. f. On tracks, &c.
Raoulia glabra Hook. f. Dry places.
—— *australis* Hook. f. Shingle-beds.
Gnaphalium luteo-album L. Not uncommon.
—— *Lyallii* Hook. f. Rocks, Martin's Bay.
Helichrysum bellidioides (Forst. f.) Willd. Not plentiful.
Craspedia uniflora Forst. f. var. *robusta* Hook. f. Common; Martin's Bay.
Cotula dioica Hook. f. Open places; common.
Senecio elaeagnifolius Hook. f. Not plentiful.

Art. XIV.—*Notes of a Botanical Excursion to Bunkers Island (Stewart Island).*

By D. L. Poppelwell.

[*Read before the Otago Institute, 12th June, 1917; received by Editors, 22nd December, 1917; issued separately, 24th May, 1918.*]

On the 7th April, 1917, in company with Mr. G. Biggar, of Croydon, I paid a visit to Bunkers, one of the group of islands off the north-east coast of Stewart Island. This scrap of land lies to the eastward of Herekopere, and is one of the Fancy Group. It is only about 700 metres long, with an average width of less than 100 metres. The highest point above sea-level is about 35 metres. The eastern end is a separate island at high tide, and in another part the island is almost cut in two by the action of the sea. The geological formation consists of rotten granite, a good deal of it being simply a sort of gritty clay. The sea has eaten into this soft material on the southern side, with the result that there are several slips and cliffs there, all of which show much recent denudation. Mr. C. Hansen, of Half-moon Bay, informs me that there is comparatively shallow water on the south and south-west of the island, which suggests that at no distant date the island was larger than at present.

Ecological Conditions.

In common with all other islands of the Stewart Group, Bunkers is subject to a high rainfall, with high winds, but a comparatively mild and equable temperature. On this island there is only a thin coating of peat. Probably it is on this account that there is but little evidence of bird traffic so far as the burrowing petrels are concerned, although penguins were not uncommon. The edaphic conditions and the exposed situation combine to prevent any extent of forest vegetation, although there are not wanting signs of a one-time forest formation. Probably when the island was larger such a formation existed, but the present plant-covering might be called a "scrub" association.

Plant-formations.

These may be divided under the heads of "scrub" and "rocks and cliffs," but with a view to saving space I do not intend to do more than outline the associations.

The physiognomy of the scrub shows a smooth exterior, and has the usual grey-green colour of the *Olearia-Senecio* association of the Stewart Botanical District. *Olearia angustifolia* is the commonest plant near the sea, but *Senecio rotundifolia* and *Veronica elliptica* are common. Curious to relate, *Olearia Colensoi*, so common in similar associations on the islands in the vicinity, appears to be absent. Here and there *Stilbocarpa Lyallii* is seen in patches, and also the common coastal ferns *Asplenium lucidum* and

A. obtusatum. Here and there are open patches covered with *Hierochloe redolens* mixed with *Pteridium esculentum* and *Histiopteris incisa*, and in other places with *Arundo conspicua.* On the higher portion of the island the principal "shrub" is *Olearia arborescens*, which grows to the dimensions of a small tree with a thick trunk and much-branched top. Great patches of *Polypodium diversifolium* are common under the scrub. The rock and cliff vegetation consists of the usual *Poa Astoni*, *Crassula moschata*, *Myosotis albida*, *Cyclophorus serpens*, *Tetragonia trigyna*, and *Apium prostratum.* I do not propose to further describe in detail the plant-associations, but am appending a list of the plants noted, from which it will be seen that a somewhat varied type of plant finds a home on this isolated piece of soil.

CONCLUSION.

The list of species shows certain surprises. I saw no sign of *Olearia Colensoi*, so common on many other islands in this locality. *Poa foliosa* and *Senecio Stewartiae*, so plentiful on Herekopere, only about a mile distant, were also absent. On the other hand, the presence of *Melicytus lanceolatus*, *Hemitelia Smithii*, *Weinmannia racemosa*, and the orchids *Earina mucronata* and *E. autumnalis* suggest a former forest vegetation, of the destruction of part of which by fire there was some evidence. The total number of species listed is seventy, belonging to fifty-three genera and twenty-eight families. In addition to these, five introduced species were noted.

LIST OF PLANTS NOTED.

PTERIDOPHYTA.

CYATHEACEAE.

Hemitelia Smithii (Hook. f.) Hook.
Alsophila Colensoi Hook. f.

POLYPODIACEAE.

Polystichum vestitum (Forst. f.) Presl.
Asplenium obtusatum Forst. f.
—— *scleroprium* Homb. & Jacq.
—— *lucidum* Forst. f.
—— *flaccidum* Forst. f.
Blechnum capense (L.) Schlecht.
Histiopteris incisa (Thbg.) J. Sm.
Pteridium esculentum (Forst. f.) Cockayne.
Polypodium diversifolium Willd.
Cyclophorus serpens (Forst. f.) C. Chr.

LYCOPODIACEAE.

Lycopodium fastigiatum R. Br.
—— *volubile* Forst. f.
—— *Billardieri* Spring.

SPERMOPHYTA.

GRAMINEAE.

Hierochloe redolens (Forst. f.) R. Br.
Arundo conspicua Forst. f.
Poa Astoni Petrie.
—— *caespitosa* Forst. f.
—— *imbecilla* Forst. f.

CYPERACEAE.

Scirpus nodosus (R. Br.) Rottb.
Uncinia pedicellata Küken. (?).

JUNCACEAE.

Luzula campestris DC.

LILIACEAE.

Astelia nervosa Banks & Sol.
Phormium Cookianum Le Jolis.

ORCHIDACEAE.

Earina mucronata Lindl.
—— *autumnalis* (Forst. f.) Hook.
Thelymitra longifolia Forst.
Prasophyllum Colensoi Hook. f.

POLYGONACEAE.

Muehlenbeckia australis (Hook. f.) Meissn.

AIZOACEAE.

Tetragonia trigyna Banks & Sol.

CRUCIFERAE.

Cardamine heterophylla (Forst. f.) O. E. Schultz var.

CRASSULACEAE.

Crassula moschata Forst. f.

CUNONIACEAE.

Weinmannia racemosa L. f.

ROSACEAE.

Acaena Sanguisorbae Vahl. var. *pusilla* Bitter.

GERANIACEAE.

Geranium microphyllum Hook. f.

VIOLACEAE.

Melicytus lanceolatus Hook. f.

THYMELAEACEAE.

Pimelea Lyallii Hook. f.

ONAGRACEAE.

Epilobium pubens A. Rich.

HALORRHAGACEAE.

Halorrhagis erecta (Murr.) Schindler.
Gunnera albocarpa (T. Kirk) Cockayne.

ARALIACEAE.

Stilbocarpa Lyallii J. B. Armstrong.
Nothopanax Colensoi (Hook. f.) Seem.

Umbelliferae.

Hydrocotyle novae-zealandiae DC.
Apium prostratum Labill.

Cornaceae.

Griselinia littoralis Raoul.

Myrsinaceae.

Rapanea Urvillei (A. DC.) Mez.

Convolvulaceae.

Calystegia tuguriorum (Forst. f.) R. Br.

Boraginaceae.

Myosotis albida (T. Kirk) Cheesem.

Scrophularinaceae.

Veronica elliptica Forst. f.

Rubiaceae.

Coprosma lucida Forst. f.
—— *areolata* Cheesem.
—— *foetidissima* Forst.
—— *acerosa* A. Cunn.
—— *parviflora* Hook. f.
Nertera dichondraefolia (A. Cunn.) Hook. f.
—— *depressa* Banks & Sol.

Campanulaceae.

Wahlenbergia gracilis (Forst. f.) A. DC.

Compositae.

Lagenophora pumila (Forst. f.) Cheesem.
Brachycome Thomsoni T. Kirk.
Olearia angustifolia Hook. f.
—— *arborescens* (Forst. f.) Cockayne and Laing.
Gnaphalium luteo-album L.
—— *collinum* Labill.
Helichrysum bellidioides (Forst. f.) Willd.
—— *filicaule* Hook. f.
Senecio lautus Forst. f.
—— *rotundifolius* Hook. f.
Sonchus littoralis (Kirk) Cockayne.

Introduced Plants.

Holcus lanatus L.
Poa trivialis Lind. (?).
Stellaria media Vill.
Brassica oleracea L.
Hypochaeris radicata L.

ART. XV.—*Notes on a Botanical Visit to Coll or Bench Island (Stewart Island).*

By D. L. POPPELWELL.

[*Read before the Otago Institute, 12th June, 1917; received by Editors, 22nd December, 1917; issued separately, 24th May, 1918.*]

ON the 10th April, 1917, in company with Mr. G. Biggar, of Croydon, I had the opportunity, by courtesy of Mr. Henry Hansen, of Half-moon Bay, of spending a few hours on the above island—one of those off the north-east coast of Stewart Island, distant about six miles from the mainland, at Half-moon Bay. The whole surface of the island is clad with a close forest and scrub association, which in parts is difficult to get through, and consequently my list can hardly be considered exhaustive, but it gives a good idea of the plant-covering. The general characteristics of the coastal scrub of all these outlying islands are very similar. This island, however, contains a forest association something like Pukeokaoka,* differing considerably from both Herekopere† and Bunkers,‡ which are its nearest neighbours. The top of the island is somewhat broken by a series of undulations, and the chief features of the vegetation are the close coastal scrub, the great quantities of *Stilbocarpa Lyallii*, and the large groves of *Dicksonia squarrosa*. The ferns of the forest-floor are of immense size, the fronds of *Asplenium bulbiferum* and *A. falcatum* attaining a height of 1·5 metres. Petrels and other burrowing-birds do not seem very plentiful except towards the southern end of the island, but penguins (*Megadyptes antipodium*) were common at the time of our visit, and appeared to be moulting The influence of these birds on the vegetation must be considerable, both on account of their traffic and by the enrichment of the ground by their droppings.

I do not intend further describing the plant-associations in detail, but append a list of species noted. From this it will be seen that these number fifty-four, belonging to thirty-seven genera and twenty-four families. For the first time, I think, *Senecio Stewartiae* is definitely reported from this island. It is plentiful at the south end, but was not seen elsewhere.

LIST OF PLANTS NOTED.

PTERIDOPHYTA.

HYMENOPHYLLACEAE.

Hymenophyllum sanguinolentum (Forst. f.) Sw.
—— *dilatatum* (Forst. f.) Sw.
—— *demissum* (Forst. f.) Sw.
—— *tunbridgense* (L.) Sm.

CYATHEACEAE.

Dicksonia squarrosa (Forst. f.) Sw.

POLYPODIACEAE.

Polystichum vestitum (Forst.) Presl.
—— *hispidum* (Sw.) Sm.

* See D. L. POPPELWELL, Notes on the Plant-covering of Pukeokaoka, Stewart Island, *Trans. N.Z. Inst.*, vol. 48, p. 244, 1916.

† See D. L. POPPELWELL, Notes of a Botanical Visit to Herekopere Island, Stewart Island, *Trans. N.Z. Inst.*, vol. 47, p. 142, 1915.

‡ See article in this volume, p. 154.

PTERIDOPHYTA—*continued.*

POLYPODIACEAE—*continued.*

Asplenium obtusatum Forst. f.
—— *scleroprium* Homb. & Jacq.
—— *lucidum* Forst. f.
—— *bulbiferum* Forst. f.
—— *flaccidum* Forst. f.
—— *falcatum* Lam.
Blechnum durum (Moore) C. Chr.
—— *penna marina* (Poir.) Kuhn.
Histiopteris incisa (Thbg.) J. Sm.
Pteridium esculentum (Forst. f.) Cockayne.
Polypodium Billardieri (Willd.) C. Chr.
—— *grammitidis* R. Br.
—— *diversifolium* Willd.

LYCOPODIACEAE.

Tmesipteris tannensis Bernh.

SPERMOPHYTA.

TAXACEAE.

Podocarpus ferrugineus Don.

GRAMINEAE.

Hierochloe redolens (Forst. f.) R. Br.
Poa Astoni Petrie.

CYPERACEAE.

Scirpus aucklandicus (Hook. f.) Boeck.
—— *nodosus* (R. Br.) Rottb.
Carex trifida Cav.
—— *lucida* Boott.

LILIACEAE.

Rhipogonum scandens Forst.

ORCHIDACEAE.

Earina mucronata Lindl.

POLYGONIACEAE.

Muehlenbeckia australis (Forst. f.) Meissn.

AIZOACEAE.

Tetragonia trigyna Banks & Sol.

CRASSULACEAE.

Crassula moschata Forst. f.

PITTOSPORACEAE.

Pittosporum Colensoi Hook. f. var.

CUNONIACEAE.

Weinmannia racemosa L. f.

ROSACEAE.

Rubus australis Forst. f.

VIOLACEAE.

Melicytus lanceolatus Hook. f.

MYRTACEAE.

Metrosideros lucida (Forst. f.) A. Rich.

ARALIACEAE.

Stilbocarpa Lyallii J. B. Armstrong.
Nothopanax Edgerleyi (Hook. f.) Seem
Pseudopanax crassifolium (Sol.) C. Koch var. *unifoliatum* T. Kirk.

UMBELLIFERAE.

Hydrocotyle novae-zealandiae DC.
Apium prostratum Labill.

CORNACEAE.

Griselinia littoralis Raoul.

MYRSINACEAE

Rapanea Urvellei (A. DC.) Mez.

SCROPHULARINACEAE.

Veronica elliptica Forst f.

RUBIACEAE.

Coprosma rotundifolia A. Cunn.
—— *areolata* Cheesem
—— *foetidissima* Forst
Nertera dichondraefolia (A. Cunn.) Hook. f.

COMPOSITAE.

Olearia angustifolia Hook. f.
Erechtites scaberula Hook. f.
Senecio Stewartiae J. B. Armstrong.
—— *rotundifolius* Hook. f.

ART. XVI.—*On the Age of the Alpine Chain of Western Otago.*

By Professor JAMES PARK, F.G.S.

[*Read before the Otago Institute, 9th October, 1917 ; received by Editors, 22nd December, 1917 ; issued separately, 24th May, 1918.*]

Plate VIII.

THE alpine chain of Western Otago consists of folded altered rocks of older Palaeozoic age. Deeply involved in the eastern folds of this chain there occurs a remarkable wedge of Cainozoic marine strata that can be traced as a narrow band from Bob's Cove, on the north shore of the middle arm of Lake Wakatipu, across the Richardson Mountains to the sources of the Shotover River, a distance of over twenty-five miles. The trend of this band is north-north-east, and its limits in that direction have not yet been defined. As exposed in the deep gorges with which the mountains are scored, the visible involvement exceeds 4,500 ft. At its southern end the thickness of the infolded beds is about 80 ft., and in the Shotover Mountains 12 ft.

At Bob's Cove, where these beds cover an area about half a square mile in extent, the succession is : Breccia-conglomerate (bottom) : sandy clay ; limestone ; sandstone, in places pebbly.

Fossil mollusca are fairly abundant, but usually badly preserved. The few forms collected by me during my survey* of the Queenstown district in 1908–9 indicated an Oamaruian (Miocene) age, but the absence of certain molluscs that are held to be characteristic of that period left the matter of their age in some doubt ; and in view of the profound involvement of these beds and the bearing this involvement has on the date of the tectonic movement that culminated in the building of the alpine chain I revisited Bob's Cove last January, and on that occasion collected from the sandstone lying below the limestone good examples of the following :—

Pecten huttoni Park.
Cucullaea alta Sowerby.
Limopsis zitteli Iher.
Cardium huttoni Iher.
Venericardia purpurata (Desh.).
Ostrea wüllerstorfi Zittel.
Polinices ovatus (Hutton).
Ancilla hebera Hutton.
Dentalium mantelli Zittel.

Of these, *Pecten huttoni*, *Cucullaea alta*, *Limopsis zitteli*, *Cardium huttoni*, *Ostrea wüllerstorfi*, and *Dentalium mantelli* are, so far as at present known, confined to the Oamaruian, and their presence may be regarded as satisfactory evidence that the Bob's Cove beds belong to the higher portion of that system, and the mountain-building movement which led to the deep involvement† of these beds took place in post-Miocene times, probably in the early Pliocene.

* JAMES PARK, The Geology of the Queenstown Subdivision, *Bull. No. 7 (n.s.)*, *N.Z. Geol. Surv.*, p. 66, 1909.
† *Loc. cit.*, pp. 60–66.

Bob's Cove, Lake Wakatipu, showing warping of the Tertiary beds. A, Bob's Cove limestone; B, fossils.

Face p. 160.]

ART. XVII.—*Notes on New Zealand Floristic Botany, including Descriptions of New Species, &c. (No. 3).*

By L. COCKAYNE, Ph.D., F.L.S., F.R.S., Hutton and Hector Memorial Medallist.

[*Read before the Wellington Philosophical Society, 24th October, 1917; received by Editors, 31st December, 1917; issued separately, 30th May, 1918.*]

Plates IX, X.

I. INTRODUCTION.

IN this series of papers, two of which have already appeared,* I am carrying out, as far as lies in my power, the views regarding species and taxonomic procedure expressed in my paper entitled "A Consideration of the Terms 'Species' and 'Variety' as used in Botany, with Special Reference to the Flora of New Zealand."† These views are by no means of my own formulating. On the contrary, they represent what I believe to be the consensus of opinion of those engaged in the only true way of studying specific distinctness—*i.e.*, by means of experiments in genetics according to present-day methods. If my views possess any originality it lies in the method of stating the case and in the proposals suggested for meeting the practical difficulty of making a flora serve its primary purpose of enabling any plant to be readily recognized and accorded its proper name. As the length of the paper cited above and the method of presentation of its arguments may serve to somewhat becloud the practical application of the theories advocated therein, I now briefly state the principles which in this series of papers are the guide for the establishing of species or varieties :—

(1.) The starting-point in the setting-up of species is the individual.

(2.) Groups of individuals which resemble one another in every character and reproduce their like, subject, of course, to unfixed fluctuating variations, constitute specific units and may be designated "microspecies."‡

(3.) One microspecies, if all its related microspecies have been obliterated or have never existed, constitutes an invariable or fixed systematic species. Examples: *Agathis australis, Veronica cupressoides, Epilobium pallidiflorum.*§

(4.) Two or more closely related microspecies may be united into a group for the sake of: (*a*) convenience in identification, (*b*) emphasizing the close relationship of minor groups (microspecies), (*c*) phytogeography.

(5.) Such a major group as constituted in (4) forms an aggregate or collective species.

(6.) Aggregate species are the "variable species" of floras. Examples: *Poa anceps, Ranunculus lappaceus, Pimelea prostrata.*

(7.) An aggregate species has obviously no real existence; it is a convenient abstraction only.

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* *Trans. N.Z. Inst.*, vol. 48, pp. 193–202, 1916; and *ibid.*, vol. 49, pp. 56–65, 1917.

† *Trans. N.Z. Inst.*, vol. 49, pp. 66–79.

‡ Other names given to such groups are "biotypes," "*petites espèces,*" and "elementary species."

§ It might well be argued that there are no species which consist of only one microspecies, and that intense study and experiment will demonstrate their polymorphy.

(8.) Each microspecies of the combination forming an aggregate species should theoretically receive a varietal name.

(9.) But in practice the procedure advocated in (8) would defeat its purpose if the microspecies were too much alike, so in this case groups of virtually identical microspecies can receive varietal rank.

(10.) It follows then that, similarly with species, varieties are of two kinds, one reproducing itself true and the other an aggregate.

(11.) Aggregate varieties, though abstractions only, so far as the eye goes approximate to true entities.

(12.) The description of an aggregate species applies to no special individual, but includes the striking characters common to all its varieties; obviously, then, there is no "type."

(13.) If the opinions as given above are accepted, a trinomial nomenclature becomes necessary, the first name being that of the genus, the second that of the species, and the third that of the variety.

(14.) If the opinion is held that every microspecies has been at one time related closely to other microspecies, it follows that even the invariable species mentioned in (3) should be given varietal names. But this procedure seems unnecessary, and perhaps mischievous, since a binomial for such species is convenient and it indicates that the specific group stands apart from all others.*

(15.) In certain cases groups, otherwise well defined, seem to be united by "intermediates" which cannot be joined to such groups or made into one or more species. Such "intermediates," according to the teachings of genetics, may be assumed to be hybrids between microspecies, and their occurrence should not forbid the separation into species or varieties, as the case may be, of the distinct true-breeding groups (microspecies) which are connected by such presumably hybrid intermediates.†

As a botanical ecologist, endeavouring to define and classify the plant-communities of New Zealand and to learn something about the physiological requirements of the species and the physiology of form, I have keenly felt, for many years, the want of names for many well-marked groups of individuals which, though fitting fairly well into one or other of the recognized aggregate species, differ so greatly in their ecological requirements from other members of the species to which they are referred that to call them by the same name is most misleading, and in no few instances will cause incorrect ecological deductions.‡

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* Of course, as at present accepted, there are many different degrees of specific isolation, but it should be possible to gradually bring about greater uniformity in this regard.

† This has frequently been done in the New Zealand flora, but not because of any special biological explanation such as that of microspecific hybrids. *Celmisia discolor* and *C. incana* (*Manual*, pp. 304–5), *Gnaphalium Lyallii* and *G. trinerve* (*Manual*, p. 323), and many species of *Veronica* are cases in point. On the other hand, distinct microspecies are denied specific rank owing to their being connected by "intermediates." Examples are: *Epilobium pedunculare* reduced to a var. of *E. nummularifolium* (*Manual*, p. 180), the treatment of the groups included under *Hoheria populnea* (*Manual*, p. 79), and the retention of vars. *robusta*, *minor*, and *lanata* as varieties of *Craspedia uniflora* (*Manual*, p. 348).

‡ Of what value would be an account of the leaf-anatomy or the rate of transpiration in the leaves of certain individuals of *Pittosporum tenuifolium*, *Acaena Sanguisorbae*, *Aristotelia fruticosa*, *Geranium sessiliflorum*, *Celmisia coriacea*, and *Myosotis antarctica* under the above specific names, unless a description of the actual plants dealt with were given—*i.e.*, unless they were accorded for the time being the status of microspecies?

It may well be argued that the trend of botanical taxonomy the world over is to bestow specific names on the varieties, thus breaking up the long-recognized aggregates into so-called "valid species." Certainly such groups distinguished by binomials are convenient for the ecologist working at synecology, but they are of far less use to the autecologist, the floristic phytogeographer, or the student of evolution or genetics than are aggregates with their varieties distinguished by trinomials. Once cease to emphasize the genetic aspect of taxonomy, away goes its philosophy—indeed, it ceases to be a science!

To apply the principles enumerated above is far from easy; they probably represent ideals impossible of full attainment. Research is demanded in many directions; above all, living material is essential—field observations as accurate as possible must be made, and experiments in the garden must finally decide those doubtful points impossible to be solved either in the field or the herbarium.

With regard to the species, &c., dealt with in the present paper I have received valuable assistance from various sources without which the work could not have been carried on. I must especially thank Mr. H. H. Allan, M.A., F.L.S. (Ashburton); Mr. B. C. Aston, F.I.C. (Wellington); Mr. H. Carse (Kaiaka); Mr. C. E. Christensen (Hanmer); Miss E. M. Herriott, M.A. (Christchurch); the Rev. J. E. Holloway, D.Sc. (Hokitika); Mr. R. M. Laing, M.A., B.Sc. (Christchurch); Messrs. Nairn and Son (Christchurch); Mr. D. Petrie, M.A. (Auckland); Mr. R. H. Rockel, M.A. (New Plymouth); Professor A. Wall, M.A. (Christchurch); and Mr. J. Young (Christchurch)—all of whom have given me much-valued aid both in material and information. I must also acknowledge the kindness of Professor H. B. Kirk, M.A. (Wellington), who has afforded me every facility for using the herbarium of the late Mr. T. Kirk, F.L.S.; of Dr. J. A. Thomson for similar privileges with regard to Colenso's herbarium in the Dominion Museum; and of Mr. A. Turnbull, F.L.S., who has allowed me to consult his splendid library of Australasian and Pacific literature.

As far as possible I have deposited in the herbarium of the Canterbury Museum, Christchurch, type specimens of all the species, &c., dealt with in this series of papers.

II. Taxonomic.

25.* Carmichaelia Fieldii Cockayne sp. nov.

Frutex parvus, glaber, afoliatus nisi juventute, prostratus. Rami usque ad 40 cm. longi sed saepe multo breviores, 2 mm. lati, arcuati, compressi, striati, pauciramosi, cortice luteo-viride obtecti. Racemi brevissimi, nunquam fasciculati, 2–5 flori; pedicelli $\pm$ 3 mm. longi, glabri. Flores non visi. Legumen 3–4 mm. longum, oblique-ovoideum vel -oblongum, quam maxime turgidum, subrugosum, nigrum; rostrum basi crassum, curvatum, apiculatum. Semina 2–5 (plerumque 3–4), pallide brunnea.

South Island: North-western Botanical District—Growing as a small colony on a wind-swept sandstone ledge on a small island rising, at low water, out of the mud-flat of Westhaven (West Wanganui). W. H. Field and B. C. Aston!

The above description is drawn up from insufficient material. In many cases the capsules were much damaged.

Carmichaelia Fieldii appears to come nearest in affinity to *C. juncea* Col., but it differs in its prostrate habit, broader always more or less

* The numbers follow on consecutively in this series of papers.

compressed branchlets, shorter fewer-flowered, racemes, glabrous pedicels, and smaller dehiscent pod, with much stouter beak, which contains not 1–3 but 2–5 seeds. From *Carmichaelia prona*, the only purely prostrate species yet described, it is distinguished at once by its leafless adult branches, dehiscing pod with longer beak and greater number of seeds.

Except for the dehiscence of the pod, the species under consideration would come into the subgenus *Huttonella*.

The plant was discovered by Mr. W. H. Field, M.P., to whom it is dedicated. Mr. Aston was with Mr. Field at the time of the discovery, and he kindly handed over to me for publication the material he had collected, gave me two living plants for cultivation and further observation, and supplied the information given above regarding the habitat and habit of the species.

26. **Carmichaelia grandiflora** (Benth.) Hook. f. var. **alba** T. Kirk.

The var. *alba* of *Carmichaelia grandiflora* was established in 1899 by T. Kirk to accommodate a plant which grows abundantly near the outskirts of subalpine *Nothofagus* forest in the neighbourhood of the junction of the White River and the main branch of the River Waimakariri, not far from their sources (Western Botanical District). There it has been collected by Kirk himself, Cheeseman, Wall, myself, and others. Cheeseman (*Manual*, p. 115) recognizes only the " type "—obviously a mixture—and var. *divaricata* T. Kirk, but (*Illustrations of the New Zealand Flora*, facing pl. 33) he writes regarding *C. grandiflora*. " It is an exceedingly variable plant. Mr. T. Kirk in his 'Students' Flora,' enumerates three varieties, and there are other distinct-looking forms. These varieties* differ in size, in the mode of branching, and in the size and shape of the pod. But before their systematic position can be properly understood they all require careful study and examination in the field." From this it is evident that, according to Cheeseman, the " varieties " of *C. grandiflora* differ from one another in virtually all the essential characters used to define the species of *Carmichaelia*.

Coming to var. *alba*, this is probably now accepted by Cheeseman as a variety, since in the *Illustrations*, when criticizing Kirk's remarks about its odour, Cheeseman writes, "Mr. T. Kirk in the 'Students' Handbook' says that the flowers 'smell disgustingly of mice.' But this peculiarity, so far as my own observations go, is only noticeable when the plant is being dried. In the fresh state the odour of the flowers is decidedly pleasant."

Since there is blossoming just now in my garden (30th December, 1917) a plant of the variety under consideration, collected for me last year by Professor A. Wall, M.A., from the original locality of the plant, I am in a position to add a few details about the variety from living material, which, unless being slightly less luxuriant and blooming more scantily, is essentially the same as if gathered from a wild plant.

Kirk describes his var. *alba* as follows: " Branchlets more robust, compressed, deeply grooved, fastigiate or nearly so. Flowers as in the typical form, but white. Ripe pods not seen. Smells disgustingly of mice " ; and he adds that it is " possibly a distinct species."

The plant in my garden is certainly not " fastigiate " ; on the contrary, the branches are wide-spreading, being 60 cm. in their spread, while the shrub is but 30 cm. high. The branches are dark green, flattened, about

* It is not clear whether the author means only Kirk's published varieties or these together with the "other distinct-looking forms," but I think the latter are meant to be included.

3·5 mm. diameter throughout for their final 15 cm. of length, grooved but not nearly to the same extent as in dried material, and more or less arcuate. The branchlets vary from about 4 cm. to 15 cm. in length ; they are inserted on the flanks of the branch at an angle of about 30° and at about 2·5 cm. distance from one another. They are straight, bright yellowish-green, striate, flat, 3 cm. wide more or less, and almost uniform in width throughout. The leaves are numerous where sheltered, and then in fascicles of 2–4 at the base of young stems ; elsewhere they are inserted in the notch of the stem at an angle similar to that of the insertion of the branchlet ; the largest are about 1·8 cm. long, 3-foliate, their petiole 7 mm. long and channelled above ; the leaflets are uniform in size, rather dull green, obcordate-cuneate, their midrib sunken above but slightly keeled beneath ; other leaves have similar characters, but they gradually decrease in size towards the tips of the branchlets until they become only 5 mm. long, or even less, and may consist of one leaflet only. In the cultivated plant the leaves are glabrous, but wild specimens show a few hairs on the under-surface, especially on the midrib. By all previous authors *C. grandiflora* is described as having glabrous leaves, but in all my herbarium specimens collected in various localities, including the classical habitat, Milford Sound, the under-surface of the leaf is more or less hairy, and sometimes considerably so. The flowers are white, except for a distinct pale-purple blotch through the median line of the standard, and honey-scented but rather cloying ; they are in lax-flowered racemes, about 16 mm. long, furnished with short peduncles 4 mm. long or less. The calyx is campanulate and 3 mm. long ; its tube is green or mottled pale purple, and the teeth are acute, small, pale purplish-brown, and ciliolate with white hairs. The standard slightly exceeds the keel, being 6 mm. long by 6 mm. broad ; the wings and keel are equal in length (5·5 mm.).

The above description corresponds, as far as changes through drying allow a comparison to be made, with that supplied by dried specimens. The var. *alba* may therefore be defined as follows : A wide-spreading shrub with the branchlets situated on the flanks of the stems, the racemes numerous, 4–6-flowered, the flowers white with a pale-purple blotch down the centre of the standard and sweet-scented, the standard as broad as long and rather longer than the keel, which equals the wings.

Up till now *C. grandiflora* var. *alba* has been recorded from its one original station only. But that it has so restricted a distribution seems highly unlikely. It is more than likely that through taxonomists working mainly with dried material the colour of the flowers has been frequently overlooked, and that specimens are now included in herbaria along with the " type," or other possible varieties, which may agree in colour with var. *alba*. How greatly colour has been neglected in diagnoses of species of *Carmichaelia* is demonstrated by the facts that Kirk mentions colour specifically in only four out of twenty-three species (*Huttonella* included) and that Cheeseman refers to colour in only seven out of nineteen species.

27. Carmichaelia juncea Col. ex Hook. f. (var. from Upper Clarence Valley).

Carmichaelia juncea Col. was described in the first place by J. D. Hooker in the *Flora Novae-Zelandiae*, vol. 1, p. 51, from specimens collected by Colenso from " east coast, Hawke's Bay and Taupo." In the *Handbook* Hooker referred plants from the East Cape (coll. Sinclair), from Akaroa (coll. Raoul), and from the Canterbury Plains (coll. Travers) to this species.

Petrie in his list of Otago plants (*Trans. N.Z. Inst.*, vol. 28, p. 546, 1896) recorded *C. juncea* from various localities in what I now call the "North Otago Botanical District." Shortly afterwards, Kirk in the *Students' Flora* accepted Petrie's determinations, and, as will be seen, enlarged Hooker's original conception of the species. Finally, Cheeseman, in the *Manual*, followed Kirk, but gave a fuller description of the species than had been published up to that time.

Both Kirk and Cheeseman agree in considering that the Otago plant may belong to an undescribed species, basing their opinions chiefly on the size of the pod and position of its beak.

On the 9th December, 1917, Mr. Christensen noted a *Carmichaelia* growing on the bank of the River Clarence (North-eastern Botanical District), between the roads leading to Jack's and Jollie's Passes, which he described as "a bush 2 ft. to 3 ft. in height, with the branches drooping over the water." He very kindly sent me specimens, one showing immature flowers (for the most part) and the other abundance of leaves. Towards the end of the month he again went in quest of fully opened flowers, and sent me a large living specimen fully in bloom, which is now growing in my garden.

The above specimens I have been able to compare with Petrie's North Otago plant and with Colenso's type specimens of the species. Below I give a full description of the Clarence Valley plant. It appears to come into the conception of the *C. juncea* of Cheeseman's *Manual*, but it differs from both the type and the Otago plant in the racemes never being in fascicles, the glabrous calyx, and the much longer calyx-teeth. I have not yet seen the pod.

As for the calyx-teeth, they are different in the three forms. In the type they are so small as to be almost wanting; in the Otago plant they are small but quite distinct, and broad at the base; in the Hanmer plant they are comparatively long and narrow. Other distinctions between the three forms may be noted on comparing the following description with Hooker's, Kirk's and Cheeseman's diagnoses.

Until fruiting specimens are received, and perhaps comparison made with living material from Hawke's Bay and Otago, which I am hoping to secure, it seems best to let the matter of *Carmichaelia juncea* remain as Cheeseman has left it. But there seems little doubt that the species as at present constituted is an aggregate, with distinct varieties of restricted distribution. As regards the Akaroa and Canterbury Plains plant I know nothing.

Description of Carmichaelia juncea *var. from the Upper Clarence Valley.*

A low shrub 60–90 cm. high, with abundant slender drooping branches and numerous short racemes of small sweet-scented flowers.

Branchlets numerous, close-set, passing from stem at a very narrow angle, bright green, compressed, but oldest branches terete, 2–3 mm. broad or rather broader but gradually tapering to an extremely narrow apex, usually leafless, glabrous. Leaves on younger branches, 1–3-foliate, $\pm$ 16 mm. long, petioles up to 6 mm. long; leaflets variable in shape and size, frequently oblong or ovate-oblong but occasionally obovate, linear, &c., retuse, bright green, glabrous above but somewhat hairy beneath with short appressed hairs, lateral leaflets much smallest, terminal $\pm$ 9 mm. long. Racemes solitary, apparently never fascicled, $\pm$ 6 mm. distant, 4–12-flowered but not dense, up to 12 mm. long; pedicels and rhachis

slightly pubescent especially when young, pedicel at most equalling the calyx, pale-coloured. Flowers minute, about 3·5–4 mm. long; calyx campanulate, glabrous, 2 mm. long (to tip of tooth), pale yellowish-cream dotted pale purple, teeth narrow, acute, rather long, dark purple; standard about 3 mm. long by 4 mm. broad, upper surface cream-coloured on lower half, above dark purple marked with almost black lines passing obliquely from median line of leaf, paler beneath, slightly exceeding the keel; wings cream-coloured more or less tinged yellow, equalling keel, oblong, rather narrow; keel near apex dark purple, beneath yellowish to cream-coloured.

28. Carmichaelia Monroi Hook. f.

Two years ago Mr. B. C. Aston, F.I.C., while investigating the flora of the Clarence River basin, collected a supposedly undescribed species of *Carmichaelia* a description of which is given below. The examination of Aston's material led me to a comparison with that in my herbarium of *C. Monroi* Hook. f., with the result that the Clarence Valley plant may be the true *C. Monroi*, and that the forms included by Kirk, Cheeseman, and others under that name may be either one or two undescribed species or very distinct varieties of *C. Monroi*. This conclusion is quite unexpected, for few species in the flora seemed to be better understood than is *C. Monroi*.

Description of Aston's Clarence Valley Species of Carmichaelia.

A stout rupestral much-branched shrub with spreading, more or less drooping, leafless branches, up to 60 cm. long. Branchlets rigid, green, flat, grooved, ± 12 cm. long and up to 9 mm. wide, hoary pubescent when young with short appressed hairs which also extend at times to the older branchlets. Racemes ± 5 cm. long, frequently 7-flowered; rhachis and pedicels densely pubescent with appressed white hairs; pedicels slender, about 6 mm. long. Flowers about 10 mm. long. Calyx campanulate, densely hairy, 5 mm. long; teeth 3 mm. long, narrow-triangular, acute, standard rather longer than the keel, 10 mm. long, 7 mm. broad, ? cream with large purple blotch in centre whence ? purple lines radiate to margin and apex; wings 6 mm. long, 2·5 mm. broad, marked with ? purple lines; keel 9 mm. long, blotched with ? purple near apex and marked with ? purple lines. Pods 12–17 mm. long, black when ripe, turgid; valves wrinkled; beak oblique (straight in one specimen), usually short but up to nearly 3 mm. long; seeds pale brown mottled with black, rather large, 3 mm. long.

South Island: North-eastern Botanical District—On shaded faces of limestone cliffs in various gorges on the south-eastern side of the Inland Kaikoura Mountains. B. C. Aston!

Had this limestone-cliff plant been the only species of *Carmichaelia* in its immediate locality, its altogether different habit, together with its much longer and wider branches and hoary branchlets, its 7-flowered racemes, and its larger flowers, would separate it from any forms of *C. Monroi* as at present understood. But on stony debris, in close proximity to the rock-plant, but in the open, Mr. Aston collected specimens of a *Carmichaelia* with short close branchlets like those of *C. Monroi* of the *Manual* except that they are pilose as in the rupestral plant. Unfortunately their pods, &c., are too immature in the specimens at my disposal for further comment.

The type of *Carmichaelia Monroi* Hook. f. was collected by Monro "from half-way up to the summit of Macrae's Run" (Awatere River basin):

Handbook of the N.Z. Flora, p. 49. Hooker's description is very short and inadequate. But the branchlets are described as glabrous, while the flowers are smaller than in the above rupestral plant. Considering that *Carmichaelia Monroi* Hook. f. and the Clarence Valley plant grow on opposite sides of the same range of mountains, and that the ecological conditions of both areas are not very different, it seems fair to offer the suggestion that perhaps Hooker neglected to note the hairy branchlets of the Awatere plant, and that the groups here discussed are not distinct, but one and the same. But this question can alone be decided by comparing Awatere and Clarence Valley material and growing both rupestral and debris plants from seed and then cultivating the seedlings under identical conditions.

Coming next to *Carmichaelia Monroi* in the sense used by Kirk and Cheeseman, this is invariably a low-growing shrub with dense erect branchlets forming open flat cushions on stony ground. But an examination of the material of this species at my disposal and a comparison with the descriptions of Hooker, T. Kirk, and Cheeseman respectively have led me to the opinion that more than one varietal group is included. For instance, Petrie's Otago specimens have glabrous calyces—a marked contradistinction to Hooker's description of his Awatere specimens as having a "hoary" calyx. Also, specimens collected by me in the Eastern Botanical District have almost tomentose calyces, while Cheeseman describes the calyx as "silky, sometimes densely so," but he does not suggest that it is ever glabrous. These Otago specimens, too, have triangular, but not narrow-triangular, calyx-teeth as given by Cheeseman, while the Eastern Botanical District plant has small calyx-teeth.

From the above it seems clear that the Otago plant at least should be separated from its allies as a variety, but I do not propose to take this step until the taxonomy of the whole group is made clear.

Again, there is an allied but much taller plant than the above cushion-form. This I have collected at Riversdale (Waimakariri River basin) and on the Waimakariri River bed on the Canterbury Plain near the protection-works. A specimen was planted by me in the gardens of the Biological Department, Canterbury College, but, unfortunately, before I could describe it, it was killed during the building of the new chemical laboratory. Another living plant was for many years in the old "native section" of the Christchurch Botanical Gardens, and it may still be there. Also, there is in my herbarium, under the MS. name *Carmichaelia humilis*, a specimen collected by Mr. Petrie in the North Otago Botanical District.

To sum up, there is a group of more or less low-growing forms of *Carmichaelia* closely allied to and including Hooker's original *C. Monroi* which does not consist of a number of identical individuals, but of minor groups distinguished from one another by well-marked characters, so that the major group is either a collection of closely allied species one of which is *Carmichaelia Monroi*, or this latter should be treated as an aggregate species consisting of perhaps five quite distinct varieties.

29. Cassinia albida (T. Kirk) Cockayne.

In *Trans. N.Z. Inst.*, vol. 38, pp. 368–69, 1906, after considerable experience both with *Cassinia Vauvilliersii* Hook. f. and the var. *albida* T. Kirk, I proposed to rank the latter as a species. Cheeseman (*Trans. N.Z. Inst.*, vol. 39, p. 446, 1907), criticizing my procedure, said that the course to be followed in this matter would "depend largely on the point of view and personal judgment of the observer, coupled, of course, with a full consider-

ation of the evidence available." More recently Cheeseman (*Illustrations of the N.Z. Flora*, facing pl. 107) accepts *C. albida* as a species.

With my views as to the relations of species and variety greatly changed since 1906, I would now reverse my decision, were it not that both *C. Vauvilliersii* and *C. albida* embrace more than one microspecies, and that if the latter were reinstated as a variety of the former it would be necessary to establish subvarieties in addition to varieties, so overburdening the nomenclature.

In *Trans. N.Z. Inst.*, loc. cit., a var. *canescens* of *Cassinia albida* is defined by me. This is distinguished from the type, to which the distinguishing varietal name "*typica*" is here given,* by the leaf being so densely covered on the upper surface with a mat of white hairs as to look as if powdered with dust or mildew.

Some time ago Professor A. Wall sent me living plants of both varieties. These cultivated in my garden have put forth many young shoots, which maintain their distinguishing varietal characters, though in var. *canescens* the hoariness is somewhat less marked. Both varieties are confined to the North-eastern Botanical District, but recent observations of Wall show that possibly neither variety extends to its southern boundary.

In addition to the two varieties dealt with above, Mr. Aston two years ago collected in the Clarence Valley a variety of *Cassina albida* which is woolly on the under-surface of the leaf and rather more hoary on the upper surface than is var. *canescens*. But, as I have only the one specimen, I merely call attention to this apparently distinct form.

It is a matter of interest that on the Lord Auckland Islands the closely related *Cassinia Vauvilliersii* (Homb. & Jacq.) Hook. f. is represented by two varieties—viz., the type and one with a canescent upper surface to the leaf. These characters are so striking that the two varieties can be recognized at a distance.†

30. Epilobium chloraefolium Hausskn.

This extremely common subalpine species was first described by Haussknecht in 1879 from dried material (*Oestr. bot. Zeitschrift*, vol. 29, p. 149). Although, as Haussknecht points out, the species bears no resemblance to *E. rotundifolium* Forst. f., the dried material which he examined in various English herbaria showed him that it had been referred to the latter. But long after Haussknecht's subjecting the New Zealand *Epilobia* to a searching inquiry—indeed, up to the publication of Kirk's *Students' Flora* in 1899—with but few exceptions, the New Zealand *Epilobia*, now known to number at least thirty-eight species,‡ as well as some strongly marked varieties, had been crammed into the Procrustean bed of Hooker's arrangement in the *Handbook*, where but seventeen species were admitted. This summary

* *Cassinia albida* (T. Kirk) Cockayne var. *typica* Cockayne var. nov. Foliis supra pilis sparsissime obtectis.

† See L. COCKAYNE, The Ecological Botany of the Subantarctic Islands of New Zealand, *The Subantarctic Islands of New Zealand*, vol. 1, p. 216, 1909.

‡ Since the publication of the twenty-eight species admitted by Cheeseman in the *Manual* the following have been described either as new or "restored": *Epilobium antipodum* Petrie, *E. arcuatum* Petrie, *E. cinereum* A. Rich. (to replace *E. junceum* Sol. in part), *E. Cockaynianum* Petrie, *E. erectum* Petrie (to replace *E. junceum* var. *macrophyllum* Hausskn.), *E. hirtigerum* A. Cunn. (to replace *E. junceum* var. *hirtigerum*), *E. nerterioides* A. Cunn., *E. pedunculare* A. Cunn., *E. rubro-marginatum* Cockayne, *E. tasmanicum* Hausskn. (the last two to replace *E. confertifolium* Hook. f. so far as it applied to plants other than those of the New Zealand Subantarctic Botanical Province).

treatment was for the most part due, I believe, to Hooker's statement in the *Handbook* (p. 76), as follows: "I have repeatedly studied the New Zealand ones [*Epilobia*], many of which completely puzzle me. The following descriptions represent in many cases perhaps prevalent forms rather than species; and the student will certainly find intermediates between most of them. It is useless attempting to name many species until copious suites of specimens are collected, the characters being to a great extent comparative."

Cheeseman's description of *Epilobium chloraefolium* in the *Manual* is excellent. However, he states (p. 178) that, though a well-marked plant, it is "at the same time a very variable one, especially in height, degree of branching, size of flowers and capsules, &c." But this variability depends, so far as my investigations go, not upon there being a number of true-breeding races (microspecies) included in either Cheeseman's or Haussknecht's groups, but rather upon true variability according to environment—shade- and sun-plants, for instance, differing greatly in certain particulars. Also, I rather suspect that certain hybrids are included by Cheeseman in his group.

In this note I am suggesting an enlargement of the conception of the species by adding a distinct true-breeding group which, although it fits well into the original description if size of organs is ignored, far surpasses the type in this respect. I am also giving a varietal name to the "type," so that to those accepting my conclusions the group *E. chloraefolium* will consist of the two varieties and of any other allied varieties which may be segregated from the individuals now constituting the species, or in course of time be discovered.

(*a.*) *Epilobium chloraefolium* Hausskn. var. *kaikourense* Cockayne var. nov.

Habitu robustiore, floribus duplo majoribus a typo differt.

This well-marked variety is distinguished at a glance from any form of *Epilobium chloraefolium* by its exceedingly robust habit and large white flowers, which at times are quite 28 mm. in diameter when fully opened.

The stems, decumbent at first, finally erect and woody in their older parts, are stout, purple, shining, smooth, and minutely bifariously pubescent. The leaves are numerous, moderately close-set, pilose especially on the margin at the base and on the petiole when young but finally glabrous, rather thick, coriaceous, somewhat glossy, bright- or yellowish-green above, often reddish beneath, and taper into a short, broad, channelled petiole about 4 mm. long; the lamina is more or less broadly oblong or even elliptic, about 20 mm. long by 12 mm. wide and distinctly but minutely toothed, its apex is obtuse, the midrib is strongly keeled, and the lateral veins distinct.

The flowers are few in the axils of the terminal leaves, white, invariably large, and often attain 28 mm. diameter. The plant continues blooming for more than six months. The capsule is about 3·3 cm. long, dark purple, minutely pubescent; its peduncle is only 3·5 mm. long—*i.e.*, it is much shorter than the subtending leaf, which may be 19 mm. long or longer. The seeds are numerous, ± 1·75 mm. long, light-brown, and papillose.

The great differences in appearance which the above-described vars. of *E. chloraefolium* present made me inclined at one time to consider the var. *kaikourense* a distinct species, especially as it came true from seed and occupied a special limited area of distribution. So long ago as 1892 Mr. T. Kirk wrote to me regarding a specimen (herb. L. Cockayne, No. 3668) I submitted for his opinion, "May prove distinct, but further specimens must be examined—a very interesting form."

A careful comparison of living plants of both varieties in my garden shows that there is no important difference between them except size, while the structure of the flower is identical in both.

The plant was found in the first instance by myself in 1892, growing in rather moist soil on cliffs a little distance from the sea at Kaikoura, and shortly after that I found it to be abundant under the subalpine scrub on Mount Fyffe (Seaward Kaikoura Mountains). Plants were cultivated in my New Brighton garden, where they, or their seedlings, remained for six years at least; and seeds were sent in 1897, and probably earlier, to various European botanical gardens under the name *Epilobium Cockaynianum** Petrie ined., but which Petrie never published. In 1905 Mr. H. J. Matthews and myself again observed the plant on Mount Fyffe, and I recorded its occurrence in *Trans. N.Z. Inst.*, vol. 38, p. 373, 1906, as *Epilobium* sp. aff. *E. chloraefolium* Hausskn. Since then the plant in question has been found by Mr. C. E. Foweraker and myself in the Awatere Valley, by Mr. B. C. Aston in the Clarence Valley, and by Professor A. Wall on the Seaward Kaikoura Mountains; while a plant from Mount Isabel, at Hanmer, collected by Mr. C. E. Christensen probably is var. *kaikourense*. In other words, the variety is confined to the North-eastern Botanical District, where it is of wide distribution from sea-level to at least 900 m. altitude, and grows on rock, beneath shrubs, and probably in shady tussock grassland.

Phytogeographically the distribution of *E. chloraefolium* var. *kaikourense* is an interesting case of a true-breeding race of a species of wide distribution being confined to a limited area which possesses a special ecological character, as reflected in the great number of locally endemic plants.

From the horticultural standpoint, the ease of culture of the plant, its general habit, beautiful long-blooming flowers, and purplish foliage and stems render it worthy of any rock-garden; nor is there fear of its becoming a weed, as in the case of certain New Zealand *Epilobia*.

(*b*.) *Epilobium chloraefolium* Hausskn. var. *verum* Cockayne var. nov.

This equals *E. chloraefolium* as described by Haussknecht in *Monographie der Gattung Epilobium*, p. 299, Taf. 19, fig. 81, 1884. No further description is needed. The differences between var. *verum* and var. *kaikourense* are given above.

31. Epilobium pedunculare A. Cunn. var. brunnescens Cockayne var. nov.

Caulibus pallidis saepe brunneis tinctis. Foliis ovato-oblongis vel oblongo-rotundatis, supra pallide viridibus saepe brunnescentibus, margine remote dentatis, subtus purpurascentibus. Capsulis glaberrimis, pallide bruneis, ± 5·3 cm. longis; pedicellis colore capsulis etiam, multo elongatis, 6·6 cm. longis.

This variety forms large more or less circular patches. The leaves vary in size, but about 9 mm. long is frequent; the petioles are about 3 mm. long. Where exposed to bright light the leaves assume a brownish tinge. The flowers are small, white, and about 5 mm. diameter. The calyx-segments are narrow-oblong, 3 mm. long, brownish, and end in a swollen purplish apex. The capsule is more than three times the length of the ovary, and the peduncle increases from about 2·2 cm. to 5·7 cm. as the capsule develops.

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* *E. Cockaynianum* Petrie in *Trans. N.Z. Inst.*, vol. 41, p. 140, 1909, has no relationship to this, but is related to *E. alsinoides* A. Cunn.

Epilobium pedunculare var. *brunnescens* has a wide range, but this I cannot at present define, nor its ecological distribution. However, I have plants in my garden identical in every particular collected from localities far distant from one another—viz., Mount Egmont (coll. L. C.) (Egmont-Wanganui Botanical District) and Four Peaks (coll. A. Wall) (south of the Eastern Botanical District).

Haussknecht describes a var. *laxa* of *E. pedunculare*, and it may be that my new variety is the same. But without actually comparing the material on which Haussknecht founded his variety it is impossible to come to a conclusion, so it seems to me better to risk the establishment of a synonym, which for a time will serve a definite phytogeographic purpose, than to withhold publication or refer the group to var. *laxa*, which it may not be after all.

The further question arises, am I right to uphold the species *Epilobium pedunculare* A. Cunn. rather than follow Hooker, Kirk, and Cheeseman, and deal with it as a variety of *E. nummularifolium?*

Haussknecht—relying only, however, upon dried material—keeps the two species distinct, and strongly supports his position by the two fine figures 94 and 96 (*Monographie der Gattung Epilobium*, Taf. 22 and 23). He also states that in herbaria *E. pedunculare* is frequently found mixed with *E. nummularifolium*, but that they are readily distinguished by *E. pedunculare* having the leaves smaller, more close-set, thicker, entire, and with shorter stalks; the capsule glabrous and its peduncle more slender, and the seeds covered much more thickly with papillae (*l.c.*, p. 303—freely translated).

My own experience, after many years' observation of various groups included under the specific names *nummularifolium* and *pedunculare*, both growing in many parts of New Zealand and also cultivated by me, has convinced me that the two species are absolutely distinct, and separated by well-marked unchangeable characters.

Epilobium nummularifolium, in one form at any rate—and the species may quite well contain only the one form—is common throughout the North and South Islands, but absent in Stewart Island; it appears to be mainly a lowland plant, but there is no exact record of its distribution, such being confused with that of *E. pedunculare*, which ascends at least to the subalpine belt.

E. nummularifolium may be best distinguished from the aggregate *E. pedunculare* by its orbicular or suborbicular bright-green leaf with at times a more or less truncate base, its rather long petiole which is winged above, its capsule not glabrous but closely covered with a short cinerescent pubescence, its fruiting peduncle not lengthening so greatly as in *E. pedunculare*, and its less papillose seeds. Even the leaves alone of living specimens enable the two species to be identified in an instant.

32. Epilobium pedunculare A. Cunn. var. minutiflorum Cockayne var. nov.

Varietas distinctissima, caulibus gracilibus rubro-purpureis, foliis parvis rotundis subrotundis vel ovatis viridibus, floribus minutis, pedunculis statu fructu solum 3 cm. longis et capsulis purpurascentibus brevibus 11 mm. longis facile distinguenda.

South Island: Eastern Botanical District—(1) Trelissick Basin, but details regarding habitat wanting: A. Wall! (2) Rakaia River bed not far from mouth of river: H. H. Allan!

The above variety is described from a plant which has been in my garden for only a few weeks, collected by Professor Wall as above.

The plant forms matted patches. The leaves vary in size from less than 3 mm. long up to about 5 mm. The reddish-purple stems, petioles, and peduncles contrast with the bright-green leaves. The flowers are white; the calyx is pale brown tinged and margined with reddish-purple; the petals are white; the slender petiole only increases from 2 cm. to 2·5 cm. when the capsule is ripe.

33. Epilobium pedunculare A. Cunn. var. viride Cockayne var. nov.

Caulibus teneris pallide viridibus; foliis oblongis vel rotundatis remote et obscure dentatis, laminis usque ad 7 mm. diam.; floribus 6·5 mm. diam., pedunculis brevibus 5–11 mm. longis; capsulis circ. 2·8 cm. longis; viridibus secundum suturam brunneo tinctis.

North Island: North Auckland Botanical District—On river-bed near Fairburn, Mangonui County. H. Carse!

This variety is readily distinguished from *E. pedunculare* var. *brunnescens* by its green leaves and stem and by the much shorter peduncle of the flower, which does not elongate to nearly the same length as that of var. *brunnescens* in the fruiting stage. The flowers and capsules are also smaller.

The plants now growing in my garden, from which the above diagnosis is drawn up, were collected specially for this paper by Mr. H. Carse as an example of the form of *Epilobium pedunculare* in his neighbourhood. Whether the above variety is identical with the plant originally described by Allan Cunningham I cannot say, for the original description is quite general and would fit almost any variety of the species.

34. Gunnera densiflora Hook. f.

In 1864 Hooker published his *Gunnera densiflora*, basing his description on specimens collected by W. T. L. Travers at an altitude of 4,000 ft. in the Acheron and Clarence Valleys—*i.e.*, it must have been collected not far from the sources of these rivers if the altitude as given is correct. For some thirty-two years no *Gunnera* was discovered that could be referred to the above species until, in 1896, I collected a species of *Gunnera* in the Craigieburn Mountains (Eastern Botanical District), at the headwaters of the Hogsback Creek, at an altitude of rather more than 900 m. Specimens were sent by me to Kirk, who referred them, apparently without hesitation, in his *Students' Flora* (1899) to *G. densiflora*. Cheeseman, in the *Manual*, working with the same material as Kirk, drew up a new diagnosis of the species based partly upon Hooker's original brief description and partly upon my not-too-well-prepared specimens. Regarding these latter Cheeseman writes that they "are the only ones I have seen that can be referred the species."

So the matter remained until, in 1911, Mr. R. M. Laing, M.A., B.Sc., during a botanical excursion towards the headwaters of the Rivers Clarence and Waiau, discovered, in abundance, on the western side of Lake Tennyson a species of *Gunnera* which, in my opinion, is equivalent to the plant on which Hooker founded *G. densiflora*.

Mr. Laing submitted his material first of all to Cheeseman, who suggested that it might quite well be *Gunnera cordifolia* Hook. f., hitherto thought to be confined to Tasmania. Later, Mr. Laing submitted specimens for my opinion, telling me also what Cheeseman had said. *G. cordifolia*

is well illustrated in *Das Pflanzenreich* (IV. 225. Halorrhagaceae, p. 108, fig. 31). After examining Mr. Laing's specimens, and comparing them with the above-cited figure, &c., I came to the conclusion that the species was either *G. cordifolia* or a variety of that species, and so dealt with it in my unpublished *Vegetation of New Zealand.*

Laing (*Trans. N.Z. Inst.*, vol. 44, pp. 65–66, 1912) drew up a detailed description of the *Gunnera* in question in the field with the living plant before him, and his and my original opinions are considered below.

Regarding the Craigieburn Mountains plant, Laing stated (*l.c.*, p. 66) that Cheeseman had informed him it was distinct from the Lake Tennyson plant, and that it had been identified by the Kew authorities as *Gunnera densiflora* Hook. f.

Learning recently that Professor Wall intended paying a botanical visit to the Trelissick Basin, I explained to him as exactly as I could—no easy matter—the precise spot where I had collected the *Gunnera* in 1896, and urged him to make a thorough search. This he most willingly did, and not only found the plant in quantity in the locality indicated, but discovered other stations for it in the neighbourhood. He secured ample material, of which he sent me abundance both living and dried, some of the former being now growing in my garden. As it is a matter of considerable phytogeographical importance to get detailed knowledge of this rather critical species of *Gunnera* I am publishing a description.

Description of the Gunnera *from the Craigieburn Mountains.*

Rhizome short, $\pm$ 19 mm. long by 5·5 mm. thick, rooting with straight roots about 8 mm. long, and giving off stout, terete, dark-brown, more or less strigose-pilose stolons each about 3 cm. long and 2 mm. diam. Leaves in rosettes of about 4 or 5 $\pm$ 3·5 cm. across; petiolate with petiole variable in length from about 2–2·8 cm., fleshy, pale often tinged pink, terete or channelled above or only near junction with lamina, pilose with strigose white hairs on back and margin but variable in this respect as to density of hairs on different leaves of same plant; lamina moderately bright green, coriaceous, usually more or less cordate at base, sometimes truncate, auricled at base with two small toothed appendages $\pm$ 2 mm. long which are bent upwards, orbicular or broadly ovate-orbicular, hairy above and on margin, glabrous beneath, rounded at apex or occasionally almost subacute, rather coarsely but sharply toothed with about 9 teeth $\pm$ 1 mm. long on each side, veins evident above and beneath, midrib stout and keeled beneath.

Flowers unisexual, numerous. Male flowers in spikes about 2·5 cm. long terminating rather stout scapes about 2·8 cm. long arising from axils of leaves and densely covered with brown strigose hairs; pedicels very short, subtended by a small narrow subulate bract about 2 mm. long; calyx-lobes 2, narrow-triangular, about 1 mm. long; petals 2, transverse, narrow linear-spathulate, much exceeding anthers, 4 mm. long and 0·5 mm. wide near the black acute apex; stamens 2, situated on base of petals, broadly ellipsoid, 2 mm. long, rounded at apex, filaments extremely short. Female crowded into a dense globose head about 6 mm. long terminating a stout, fleshy, pale or pale-brown scape 10 mm. long, pilose with numerous white hairs; calyx-tube urceolate, pale green, smooth, about 2 mm. long; calyx-lobes 2, subulate, purple with black tip, about 0·75 mm. long. Styles 2, wide-spreading, pale brown, 4–5 mm. long, stigmatic throughout.

On compa ing, detail by detail, the above description with that of Laing (for the Lake Tennyson plant), of Schindler (for the Tasmanian plant),

and of Hooker (for the type of *Gunnera densiflora*), my opinion is that the New Zealand plants are all one and the same, and that the Tasmanian may also belong to the same species. On the other hand, the New Zealand *Gunnera*, accepting Schindler's description and illustration of the Tasmanian, differs from the latter in the petals, which are much longer and narrower in the New Zealand than in the Tasmanian plant, and in the shape of the drupe, pyriform in the New Zealand, ovoid according to Hooker ex Schindler in the Tasmanian plant. Also Schindler's figure shows the margin of the leaf of his plant as strongly ciliated, whereas in the New Zealand plants the ciliation is virtually confined to young leaves. Bearing the above in mind, it seems best to maintain *Gunnera densiflora* as a species, but to remember that it is extremely closely related to *G. cordifolia* Hook. f. of Tasmania, and is a further link between the floras of the eastern Australian and New Zealand regions.

35. **Haastia recurva** Hook. f. var. **Wallii** Cockayne var. nov.

Foliis et capitulis quam illa typi minoribus; plerumque pilis albidis munitis sed eis prope ramulorum apices interdum subfulvidis tinctis; bracteis involucri apiculatis.

The variety differs from any example of *Haastia recurva* that I have seen hitherto in the much smaller size of all its parts, in its dense wool being white nearly everywhere and only slightly fulvous near the apices of the branchlets, and in the apiculate apex of the involucral bracts. The leaves are generally less than 10 mm. long, or only half the length of good-sized leaves of the type. The flower-heads are 7 mm. diam., or not half the size of medium-sized heads in the type.

The plant was collected by Professor A. Wall on a shingle-slip near the summit of Mount Fyffe, Seaward Kaikoura Mountains. Unfortunately, only the one plant was noted. On receiving the specimen I thought this plant with white wool and slender branches might be the common form of the Kaikoura Mountains in general, but upon comparison with Mr. Aston's specimens from Mount Tapuaenuku (Inland Kaikoura Mountains) this apparently is not the case. Specimens from Shingly Range (Awatere) also belong to the type.

36. **Haastia Sinclairii** Hook. f.

Judging from specimens in my herbarium, there appear to be two distinct groups of plants included under *Haastia Sinclairii* Hook. f. by Cheeseman (*Manual*, p. 321). One of these groups is figured in Cheeseman's *Illustrations of the N.Z. Flora*, pl. 100, and this appears characteristic of the species so far as the North-western and Western Botanical Districts are concerned; but the Fiord Botanical District group appears to differ in certain particulars as compared with the more northern plant, especially in its smaller leaves, which are covered beneath much more thinly with fulvous (not white) wool, and above are thinly covered with wool or, at times, almost glabrous. Also, the heads of the Fiord plant are much smaller. I do not propose here to separate the species into two varieties, the intention of this note being to call the attention of collectors in the area of the species to probable differences in plants of this species which they may find.

In the *Illustrations of the N.Z. Flora* Cheeseman comments upon the distribution of *Haastia Sinclairii* as follows: "*H. Sinclairii*, which is a true 'shingle-slip' plant, never found away from the slopes of dry shingle which form such a prominent feature on the eastern side of the Southern Alps."

And farther on—" But it was soon found to have a wide distribution on the eastern side of the Southern Alps, and is now known to extend from the northern portions of the Mount Arthur Range southwards through the Canterbury Alps to the south-west of Otago. . . . I am not aware, owever, that it occurs in any locality well on the western side of the watershed of the Alps."

The above statements, though topographically true in our present state of knowledge, neglect the ecological viewpoint. There are two distinct classes of shingle-slips—the one very dry on the surface and situated beyond the average limit reached by the western rainfall, and the other not by any means so dry a station, since it lies within the wet area. These two classes of shingle-slip are clearly defined by their plant inhabitants. A dry or eastern shingle-slip contains that wonderful assemblage of which the following, to cite only a few, are characteristic: *Craspedia alpina*, *Notothlaspi rosulatum*, *Poa sclerophylla*, *Ranunculus Haastii*, *Stellaria Roughii*, *Veronica epacridea*. On the other hand, the western shingle-slip contains none of the above species; in fact, there are but few plants common to both—*e.g.*, *Epilobium pycnostachyum* is one. The species of *Haastia*, too, are an especially good index. On an eastern shingle-slip (using the term ecologically and not as used in the quotation above) *Haastia recurva* is alone to be found, but on a western shingle-slip it is absent, being represented by *H. Sinclairii*. So, too, the dry east gives *Veronica Haastii*, but once well into the area of excessive rain it is *V. Haastii* var. *macrocalyx*.

As for *Haastia Sinclairii* not having been found to the west of the actual Divide, I suspect this is chiefly due to the fact that shingle-slip is not much in evidence on the west, speaking comparatively, and also that, the North-western Botanical District excepted, few collections have been made on mountains possessing shingle-slips, these true western mountains being almost entirely unexplored botanically.

37. Hymenanthera crassifolia Hook. f.

Hymenanthera crassifolia Hook. f. was originally a mixture of *Scaevola novae-zelandiae* A. Cunn., now known as *Hymenanthera novae-zelandiae* (A. Cunn.) Hemsley, and plants from Cape Palliser and Nelson. These latter, along with certain other plants, form *H. crassifolia* in its restricted sense. But the distribution of the species is uncertain, owing to lack of knowledge as to the limits of polymorphy to be allowed or the variation which takes place not only in *H. crassifolia* but in the species next dealt with—*H. obovata* T. Kirk.

At any rate, so far as I know, true *H. crassifolia* is found in the Ruahine-Cook Botanical District, on the coast both of the Wellington and Sounds Subdistricts, whence it extends, but not in an unbroken line, to the coast of the South Otago Botanical District. Certain inland plants have been referred to this species, as also a Stewart Island plant, but all these determinations must be received with caution.

Although there is an admirable plate of *H. crassifolia* in the *Flora Novae-Zelandiae*, there is no description easily available which deals with the colour of the flower, and as this is an important character for identification purposes the following description of the flower may prove useful.

Description of Flowers of Hymenanthera crassifolia *Hook. f.*

Flowers inserted on under-surface of twigs, numerous but quite hidden from view on living plant, very small, usually solitary but close-set, her-

maphrodite, slightly sweet-scented, pedunculate with decurved or straight green peduncle rather shorter than the flower, furnished with two minute, broadly triangular, scarious brown bracts inserted a little below its centre. Sepals orbicular, about one-half length of petals, green with broad, purplish, minutely fimbriate margin. Petals waxy in appearance, lemon-yellow, oblong, ± 3 mm. long, obtuse, recurved at apex which on margin is sometimes purplish; in bud deeply stained purple.

The pollen is shed just before the flower opens or shortly afterwards and so easily falls on the stigma. There is no honey. Abundance of pollen reaches the stigma. After pollination the ovary, &c., rapidly enlarges.

In the neighbourhood of Wellington *H. crassifolia* commences to bloom some time during the first two weeks of September.

38. **Hymenanthera obovata** T. Kirk.

Hymenanthera obovata, as established by T. Kirk in 1895 (*Trans. N.Z. Inst.*, vol. 27, p. 350), and upheld by Cheeseman in 1906 (*Manual*, p. 50), is based on material from two sources—the Trelissick Basin (Canterbury) and various localities in Nelson. An examination of the type material in Kirk's herbarium shows that the Trelissick and Nelson material look very different, and the feeling at once arises that the species as at present constituted is a combination of two distinct groups of individuals, each of which is entitled to rank as a species.

The above difficulty is increased, firstly, by the imperfect knowledge of the flowers of either the Trelissick or Nelson plants, and, secondly, by the discovery by Mr. B. C. Aston, some years ago, of another group of individuals with, it is now known, a local distribution along the shores, &c., of Cook Strait from the French Pass and Kapiti Island to Somes Island in Wellington Harbour. This last-named group far more closely resembles the Nelson than the Trelissick group—indeed, when the flowers of the Nelson group are investigated it possibly will be found either that the two groups are identical, or that they are microspecies which must be united under one name. Likewise, judging from Kirk's type specimens, from my personal knowledge of the genus *Hymenanthera* in the Trelissick Basin, and from fresh specimens of the plant in question recently collected in the above locality by Professor Wall, it seems not unlikely that the Trelissick group may eventually be referred to *H. crassifolia*.

The present state of knowledge regarding *Hymenanthera obovata*, which I have attempted to concisely indicate, demands that any further knowledge should at once be made available for students and collectors, so that the real status of the species, and of the groups cited above, may be established.

Thanks to Mr. Aston, who last year (1916) put me in the way of seeing the Wellington plant in more than one locality, and who assisted me in collecting ample flowering material, I am in a position to describe the Wellington plant. Further, Mr. Aston at the close of the year 1917 collected material of the Nelson plant from the Riwaka–Takaka hills, which he has placed in my hands. Finally, Professor Wall has procured for me living and dried material of the Trelissick plant; while Miss Herriott (Biological Laboratory, Canterbury College) sent me some time ago from Cass (Waimakariri River basin) seedlings of the *Hymenanthera* of that locality, which must be either *H. obovata* T. Kirk (in part) or *H. dentata* var. *alpina*, another group of quite uncertain position.

Description of the Wellington Coastal Hymenanthera (= ? H. obvata *T. Kirk in its restricted sense*).

A low shrub more or less flattened to the substratum into which its prostrate stems root, but its height varies with regard to degree of exposure of the plant.

Branches more or less divaricating and interlacing, with younger twigs clad with pale bark covered with a fine pubescence, but older twigs having grey bark dotted freely with lenticels.

Leaves obovate or oblong-obovate, varying greatly in size according to situation, but from 1 cm. long by 7 mm. wide to 3 cm. long by 1·6 cm. wide are a fair average, though there are others both larger and even smaller, very dark green above, whitish-green beneath, very thick and coriaceous, obtuse, often emarginate, generally entire but occasionally there is a coarse tooth on either side,* above veins obscure, beneath evident but not numerous; petiole short, about 3 mm. long. (In shade reversion-shoots occur with leaves thinner, larger, more irregular in shape, sometimes rhomboid, 1–2-toothed on either side.)

Flowers numerous, about 4 mm. diam., mostly on the naked branches, in the axils of former leaves, solitary or in fascicles of about 4, apparently hermaphrodite, almost twice as large as those of *H. crassifolia* (see above, No. 37), paler yellow, more urceolate, and margins of petals edged with a bright-purple line; pedicels about 4 mm. long, pale green, fleshy; bract broadly triangular, acute; sepals 4–5 times shorter than petals, much broader than long, green at base but strongly margined with purple, rounded at apex which is fimbriate; petals linear-oblong or narrow ovate-oblong, about 5 mm. long and 2 mm. broad, pale yellow, obtuse, sometimes emarginate, strongly recurved; stamens with orange staminal process; scale (nectary) obovate; slightly praemorse at fimbriate apex, and abundance of honey at base.

Apart from the much greater size of the leaves, and, where not exposed to the most powerful wind, the much more open character of growth, the above species is distinguished at once from *H. crassifolia* by the flowers, which are twice as large, the sepals not half length of petals but only one-third or one-fourth as long, the narrower, longer, pale-yellow not lemon-yellow petals.

With regard to Nelson specimens of undoubted *Hymenanthera obovata* (in the restricted sense), Aston's specimens are from two sources. The first grows "in crevices of limestone rock at from 2,500 ft. to 2,700 ft. on the Riwaka Hill, and 1–3 ft. high" (*fide* Aston). Specimens of this plant show (as described for the Wellington plant) the leaves linear-obovate to occasionally almost linear, very numerous, alternate or fascicled, from more than 4 cm. long to 1·5 cm. or even less, not thick, probably rather dark green above, pale beneath, tapering into a short petiole, entire, rounded at apex. The second was taken from one plant growing at Golden Bay, near the cement-works. It was a "shrub with trunk about 10 ft. high and pendulous branches growing in shade on limestone country" (*fide* Aston). This specimen has leaves up to 7·5 cm. long, some are 3 cm. broad, quite small leaves are rare. They are bright green above, pale beneath, entire, occasionally emarginate, not in fascicles.

Although the two plants just noted differ so far as the leaf is concerned in some particulars from the Wellington plant, such differences are probably

* The *Manual* description reads, "quite entire," but even Kirk's type specimens show some leaves not entire.

[J. E. Young, photo.

Leptospermum scoparium Leonard Wilson, growing naturally near Port Levy, Banks Peninsula.

[J. E. Young, photo.

Flowering branch of *Leptospermum scoparium* Leonard Wilson, showing the double white flowers.

entirely environmental. The most interesting point is the greatly reduced leaves present with much larger ones on the Riwaka plant, and such suggest that perhaps the Trelissick Basin plant is, after all, a reduced form. An examination of flowers and fruit can alone settle this interesting point, but I am still inclined to agree with my opinion as stated above — that the Trelissick plant is one species, and that the Riwaka and other Nelson plants should be united with the Wellington plant either as a polymorphic or an epharmonic group.

39. Leptospermum scoparium Forst. (forms with double flowers). (Plates IX and X.)

In *New Zealand Plants and their Story*, p. 149 (1910), I have called attention to a form of *Leptospermum scoparium* with double flowers which was discovered by Mr. E. Phillips Turner, F.R.G.S., in the Volcanic Plateau Botanical District.

A second plant with double flowers was found some four years ago at Torrent Bay, Nelson, by a lady residing at Motueka. This information I received from Messrs. Nairn and Sons, nurserymen, of Christchurch.

A third plant with double flowers must now be recorded. This was found recently by Mr. Leonard H. Wilson on his property at Port Levy, Banks Peninsula. I am indebted to Mr. J. Young, Curator of the Christchurch Botanical Gardens, for calling my attention to this interesting plant and for supplying the fine photograph (see Plate IX) of the wild plant in its original habitat, the photograph being taken by his son, Mr. James E. Young. Cuttings from the Port Levy plant were struck by Mr. Young, so that there is now a vigorous specimen in the collection of New Zealand plants in the Christchurch Botanical Gardens.

Since the doubling of flowers is essentially a teratological phenomenon, one cannot look on such a race, capable only of being reproduced artificially from cuttings or layers, as equivalent to a taxonomic variety. I would propose for it the garden name of "Leonard Wilson," the plant to be known therefore as *Leptospermum scoparium* Leonard Wilson.

40. Myrtus Ralphii Hook. f.

This species was founded by J. D. Hooker on specimens collected by Dr. Ralph near the City of Wellington in the very early days of the province, and on the east coast of the North Island by Colenso, and it was first published in the *Flora Novae-Zelandiae* in 1853. Later, in the *Handbook of the New Zealand Flora*, Hooker suggested that it might be a variety of *Myrtus bullata* Sol. The species was accepted by T. Kirk (*Students' Flora*, p. 165) and by Cheeseman (*Manual*, p. 169), both authors agreeing that it is closely allied to *M. bullata*.

During the last few years I have had ample opportunity for examining the "species" in the field, and in consequence have come to the conclusion that it is a polymorphic hybrid between *M. bullata* Sol. and *M. obcordata* (Raoul) Hook. f.

My reasons for the above conclusion are (1) that the "species" is never to be found unless both *Myrtus bullata* and *M. obcordata* are present, and (2) that the individuals are strongly polymorphic even when growing in close proximity, some closely approaching *M. bullata* and others *M. obcordata*, while leaves of the *obcordata* and *bullata* types occur frequently on the same individual.

I do not think a much better example can be found of the often-mentioned "series of intermediate forms" connecting two species than is to

be seen in the multiplicity of forms assumed by *M. Ralphii* and connecting *M. bullata* and *M. obcordata*. Thus, to those believing that "intermediates" obliterate the distinctions between groups which if not so connected would be species, the only logical course to take would be either to unite all three species of *Myrtus* under the earliest name, "*bullata*," or to uphold *M. bullata* and *M. obcordata*, which form the unlike poles of the series, and to treat the intermediates—*i.e.*, *M. Ralphii*—as unnamed varieties of whichever of the two species they most resembled. For action of this kind the New Zealand and many other floras offer ample precedent; indeed, one or other of the methods suggested above would be the orthodox taxonomic course to pursue. All the same, the most inveterate "lumper" could not bring himself to unite groups so absolutely different as those represented by *M. bullata* and *M. obcordata*.

Some exact details regarding the polymorphy of *Myrtus Ralphii* may here be given in support of my contention that it is of unfixed hybrid origin.

On and near the saddle joining the Kaukau Range and Mount Crowsnest, near Wellington City, there is a remarkable scrub-association which owes its presence to excess of wind. In certain places near its outskirts there is abundance of the three species of *Myrtus* mentioned above growing side by side. Although frequently somewhat stunted in habit, *M. bullata* can be recognized at a glance; so too, generally, with the individuals of *M. obcordata*. But on examining the bushes of *M. Ralphii* it is seen at once that there is no uniformity amongst the individuals, some coming somewhat near to *M. bullata* in colour, shape, and blistering of leaf, while others are far more of the *obcordata* type—some, indeed, being almost identical with that species. Thus a hybrid origin is at once suggested, and close examination for and against such a supposition demanded.

Happily for such an investigation, *Myrtus bullata* and *M. obcordata* possess certain well-marked distinguishing characters. Thus, taking the leaves alone, even were the flowers of the two species identical, so different are the leaves that no taxonomist would unite the species. For *bullata* there is (1) the large leaf, (2) its bullate surface, (3) its usually acute apex, (4) its power of becoming reddish-brown when exposed to the sun, and (5) the base of the lamina not narrowed into the petiole. True, the bullate surface may be strongly flattened in a plant grown in complete shade, but it is always present more or less and is a marked unit-character. Then, for *obcordata* there is (1) the small leaf, (2) the rounded emarginate apex, (3) the flat surface, (4) the tapering base of the lamina, and (5) the more feeble response to coloration by intense light.

A number of specimens were collected of the three "species" of myrtle growing side by side on the outskirts of the wind-swept scrub, each specimen being taken from one individual. Of these, after examination, some were put on one side as true *Myrtus bullata*, others as true *M. obcordata*, and twenty-two were considered to be *M. Ralphii*.

A closer examination of these twenty-two showed that the specimens fell into two classes—the one with large brownish-red, more or less bullate leaves, and the other with much smaller, greener, and flatter leaves. *But these differences affected only the bulk of the leaves of each specimen.* From even the largest-leaved specimens with leaves of *bullata* type small leaves of *obcordata* type were picked. Any of the fundamental characters mentioned above might be present, absent, or even combined. The twenty-two *M. Ralphii* specimens were each numbered and examined in detail. Here are a few results:—

No. 1 had leaves about 17 mm. long by 15 mm. broad, with reddish slightly bullate surface, the apex subacute, and the lamina-base not tapering —*i.e.*, they were almost pure *bullata* type. But other leaves were only 10 mm. long by 9 mm. broad, and had the *obcordata* lamina-base, while one leaf was slightly emarginate.

No. 4 had many obovate leaves, but others tapered at both apex and base of lamina, and in one case the apex was acute; some were almost flat and some slightly bullate.

No. 5 had its slightly bullate leaves generally emarginate with tapering lamina-base; some leaves were almost rotund. This specimen might well have been taken for *M. obcordata* were it not for the slightly bullate leaves.

No. 7 had leaves up to 19 mm. long by 15 mm. broad, their apex generally rounded or subacute, but the bases of the laminae generally tapered and a few leaves had an emarginate apex.

No. 8 showed little sign of any *obcordata* character, but a few leaves had their bases strongly tapering.

No. 9 was a distinct form with the large (20 mm. by 15 mm.) leaves pale green, but here again actual obcordate leaves were present.

No. 10 strongly approached *M. obcordata*, but traces of the bullate surface were present, while in some leaves the emarginate apex was wanting and in many not strongly developed.

No. 14 was a distinct form with quite small leaves, but these were distinctly of the *bullata* type, though even here one obcordate leaf was noted.

No. 16 is specially worthy of mention. It had bright-green flat leaves, small, but larger than in *M. obcordata* of the locality. There was hardly a trace of emarginate apex, and the base of the lamina did not markedly taper. Here the most characteristic feature of the series of intermediates —the more or less bullate surface—was absent, but so was the emarginate apex of *M obcordata*.

No. 17 was similar to No. 16, and were it not for the number of leaves with non-emarginate apex and a very slight trace of a bullate surface here and there the specimen would be *M. obcordata* pure and simple.

My contention of the hybrid origin of *Myrtus Ralphii* does not rest upon the above examples alone. At the "Meeting of the Waters," near New Plymouth, there, not in a wind-swept habitat, but in the moist, still atmosphere of the forest-interior, I saw an astonishing series of intermediates between *M. bullata* and *M. obcordata*, both these species being also present. It was seeing these plants, indeed, which first suggested the theory of hybrid origin, and which led me to carefully examine the plants of the Wellington wind-scrub. Unfortunately, I was not in a position at the time to secure material for a searching examination.

At Kenepuru Inlet, Marlborough Sounds, I collected specimens of *Myrtus Ralphii*. At that time I had no suspicion of its hybrid origin, or I should have collected far more copiously and taken special notes. But the specimens did strike me as not typical *M. Ralphii*. Examining them (five specimens) now I see that most of the leaves are more or less rotund, large, ± 15 mm. long, and have little trace of a bullate surface. But an emarginate apex is present in a good many cases, and occurs on leaves even 10 mm. long. One specimen has much smaller leaves, obcordate or broadly obovate, and it may be true *M. obcordata*.

In Colenso's herbarium, now to be consulted at the Dominion Museum, Wellington, there are a number of Hawke's Bay specimens of *Myrtus Ralphii*. Amongst these there is no uniformity, and they present features such as already described.

The distribution of *M. Ralphii* needs a few words. As Cheeseman has pointed out, it is a local plant and occurs throughout the North Island, Ahipara being the most northerly locality yet recorded. This is the only locality in Mangonui County known to Carse (*Trans. N.Z. Inst.*, vol. 43, p. 210, 1911), but *M. obcordata* and *M. bullata* grow in the same locality, which, like *M. Ralphii*, is according to Carse the only locality for the former. Here is indeed a crucial case. *M. bullata* is common throughout Mangonui County, according to Carse (a most trustworthy observer); *M. obcordata* is only known at Ahipara, but this, too is the sole station for *M. Ralphii!*

Without going into further details, I think all must agree that a strong case is made out for the hybrid origin of *Myrtus Ralphii*. How far all the individuals are actually the F1 generation between *M. bullata* and *M. obcordata* it is impossible to say, but the extreme polymorphy suggests that F2 and perhaps other generations are present where individuals are abundant. It is also interesting to see how certain characters may appear unchanged (pure), how others are obvious mixtures, and how others are suppressed; but without actual breeding experiments no conclusions can be drawn.

Taxonomically the only change demanded if *M. Ralphii* be considered a hybrid is to write the name thus: × *M. Ralphii*.

Appendix.

Since writing the above I have received from Mr. R. H. Rockel, M.A., a representative collection of the myrtles growing in the forest at the "Meeting of the Waters," near New Plymouth. Each specimen of the sixty-one specimens sent was taken from a different individual, and so great has been the care exercised by Mr. Rockel and a friend of his who assisted in the work that probably nearly every form of the area in question is represented.

A casual glance at the collection shows that my former word "astonishing" used with regard to the polymorphy of *Myrtus Ralphii* in that locality is no exaggeration. A more detailed examination of the material shows every gradation between typical *Myrtus obcordata* and typical *M. bullata*; there are, in fact, specimens which could be called "giant *obcordata*" and "dwarf *bullata*." There is also a series of specimens which match the figure (No. 94) of *M. Ralphii* in Kirk's *Forest Flora*. Though, taken as a whole, the specimens can be arbitrarily divided into a number of groups, the majority of the specimens has each its special characteristics. The following call for particular mention:—

(1.) Leaves stained brown, slightly bullate, apex rounded usually but some with obtuse apex and one or two slightly emarginate, bases rounded or tapering; lamina generally large—*e.g.*, 2·5 cm. by 2·3 cm.

(2.) Leaves similar to those in No. 1 but very pale green in colour.

(3.) Leaves quite of *obcordata* type so far as size, base, and colour go, but none are obcordate.

(4.) Leaves similar to those of No. 3 but considerably larger, but one or two of the smallest leaves are true *obcordata*.

(5.) Leaves for the most part very deeply stained with purple, base much tapering, apex rounded or subacute, blistering considerable, lamina frequently about 1·9 cm. by 1·2 cm.

(6.) Many leaves almost rotund but all with emarginate apex, lamina averages about 11 mm. by 11 mm.

(7.) Most of the leaves large, deeply coloured with purplish-brown, somewhat bullate, and suddenly narrowed into an acute apex, but some of the smaller leaves have a rounded apex.
(8.) Leaves strongly bullate, apex rounded but occasionally emarginate in the smaller leaves, average lamina about 1·7 cm. by 1·5 cm.
(9.) Average lamina only 8 mm. by 6 mm., surface flat, hardly a trace of emarginate apex.
(10.) Leaves tapering both at apex and base, most rather large, flat, one or two rather large obcordate leaves present.

Comparing the series of specimens just dealt with, on the whole each specimen shows more uniformity than in the Kaukau-Crowsnest series, but this may be due, in part, to the specimens being smaller. There does not seem to be any evidence of a fixed race being present.

41. Senecio (the coastal species of West Wanganui Inlet, hitherto referred to *S. rotundifolius* (Forst. f.) Hook. f.

In *Trans. N.Z. Inst.*, vol. 39, p. 446, 1907, Cheeseman records, without special comment, *Senecio rotundifolius* as growing at West Wanganui Inlet. Earlier (*Manual*, p. 383, 1906) the same botanist had referred the shrub common near Cape Foulwind to the same species. More recently Petrie (*Trans. N.Z. Inst.*, vol. 46, p. 30, 1914) has referred, "without hesitation," the Cape Foulwind plant to *Senecio elaeagnifolius* Hook. f., stating, "I examined a great many specimens of this shrub [the Cape Foulwind plant], and found that the leaves, though more coriaceous than usual, are nearly always longer than broad, in outline more or less ovate or ovate-oblong, and not rarely waved or repandly toothed at the margin. At an elevation of 2,300 ft. or so on the Longwood Range, Southland, specimens of *S. elaeagnifolius* may be seen in the forest with leaves approaching those of *S. rotundifolius* much more closely than do any to be found near Cape Foulwind."

Recently I have received from Mr. B. C. Aston a living specimen, but not in flower, of the West Wanganui *Senecio*. This specimen I should certainly hesitate to refer either to *S. rotundifolius* or to *S. elaeagnifolius*. For instance, it differs at once from both species in that the branchlets, the very youngest excepted, are covered with a smooth, not grooved, purple bark altogether lacking tomentum but, in part, most minutely pubescent, whereas similar, or indeed older, branchlets of the other two species are densely covered with pale-buff tomentum. Also, the tomentum, of the under-surface of the leaves is rather thin, white and not buff as in *S. rotundifolius* and *S. elaeagnifolius*, and puts one in mind of that of *Olearia arborescens* (Forst. f.) Cockayne and Laing. The youngest branchlets are covered more or less with a white pellicle of hairs, through which the purple bark soon becomes visible. In addition, the shrub, according to Mr. Aston's notes, is only a few feet high, and not almost a tree as is *Senecio rotundifolius*. But this low stature may be caused by the plant growing on cliffs, the only habitat where it was noted.

As for shape, none of the leaves are rotund, but obovate and oblong are the commonest forms. The leaf-base is slightly unequal and cuneate, but such a base is shown in specimens of *Senecio rotundifolius* which I collected at Anita Bay (Fiord Botanical District). The midrib is much keeled, sometimes glabrous or almost so for its entire length, or it may be covered by a thin pellicle of white hairs.

From the above it seems clear that the taxonomic position of the West Wanganui Inlet plant is quite uncertain; it may indeed be, as Mr. Aston suggests, an undescribed species. It is certainly not typical *Senecio rotundifolius*, the northern limit of which appears to be Jackson's Bay, as stated in the *Manual*. Neither is it typical *S. elaeagnifolius*. At present it seems best to look upon it as belonging to a group confined to the North-western Botanical District which may be either a distinct species or a variety of either *S. elaeagnifolius* or *S. rotundifolius*.

42. **Sophora prostrata** Buch.

Buchanan described *Sophora prostrata* as a "rigid prostrate rambling shrub 12–18 in. high" (*Trans. N.Z. Inst.*, vol. 16, p. 395, 1884). Kirk and Cheeseman both describe it as prostrate. That it frequently is quite prostrate and but a few centimetres high is true enough, but this extreme degree of depression appears to be due entirely to its environment. The really important characters which distinguish the species from any of the other species of *Sophora* are its divaricating growth-form, the smaller flowers solitary or in pairs, the standard almost equalling the wings, and the small pod with few seeds. Specimens more than 1·8 m. high, and probably much higher, are common enough, but they never grow out of the divaricating growth-form stage of development. The species reproduces itself true from seed.

The actual southern limit of *Sophora prostrata* has not been ascertained, but it does not seem to extend into the North Otago Botanical District, although the conditions there are ideal for its requirements. Personally, I have not seen it on the Canterbury Plain south of the Rakaia River, nor in the mountainous area to the south of the Waimakariri River basin. According to Cheeseman (*Manual* p. 123), *S. prostrata* is found in the mountains. But it also occurs in the lowland belt, nor do I think it ascends much above 900 m.

43. **Veronica salicifolia** Forst. f. var. **angustissima** Cockayne var. nov.

Foliis lineari-lanceolatis, racemis longis gracilibus laxifloris, calycis lobis anguste lanceolatis acutis.

North Island: Ruahine-Cook Botanical District—Otaki Gorge, base of Tararua Mountains, on more or less stony ground. L. C.

This variety is distinguished at once from any other described variety of *Veronica salicifolia* by the following combination of characters: Linear-lanceolate thin leaves ± 10 cm. long by ± 10 mm. broad, slender racemes ± 17 cm. long with the flowers rather distant, the rhachis and pedicels most minutely pubescent, the deeply-cut calyx almost as long as the corolla-tube with long narrow lanceolate acute segments, the white corolla, and the far-exserted purple anthers.

When not in bloom the plant might be easily confused with broad-leaved forms of *Veronica angustifolia* A. Rich., but from that species it is at once separated by the much longer racemes, the larger calyx, and the narrow acute not obtuse calyx-segments.

III. Phytogeographic.

Although the localities given below have for the most part not been recorded hitherto, in this series of papers the station of a species, though already published, if it is not generally known, will in certain cases be

given. Another class of species, the distribution of which requires defining with much more detail, includes those mentioned in the *Manual* as "often local," "probably not uncommon but easily overlooked," and similar statements.

The distribution of varieties needs far greater attention than is usually accorded them. The variety and not the aggregate species being the real entity, until varietal distribution is put on a sounder footing any truly scientific discussion of the distribution in general of the New Zealand flora will not be possible. What are really wanted from the evolutionary and historical standpoints are accurate records both of the distribution of the aggregate species and of the microspecies which compose them; but before such a study is possible many so-called "valid species" must be joined together as aggregates, while many more varieties of the present aggregates must be constituted.

The crying need of New Zealand floristic botany on the phyto-geographical side is undoubtedly a much more intensive study of distribution. Full lists of species, &c., for unbotanized localities are demanded. The critical points, where two botanical districts join one another, require a most intensive study. These boundaries at present are nearly all highly problematical, even in areas apparently well known. The botanical hunt should not be merely for "something new": the presence or absence of the commonest species is generally a matter of far greater importance than the finding of a rarity.

1. Acaena saccaticupula Bitter.

South Island: North-eastern Botanical District—(1.) Eastern part of Hurunui River basin: A. Wall! (2.) Trelissick Basin, Canterbury, at about 900 m. altitude: A. Wall!

This species is *Acaena adscendens*, in part, of the *Manual*. It is apparently common on the eastern side of the Southern Alps generally, but is not usually found in great abundance in any station. It appears to occur chiefly in wettish ground. Exact information as to its ecological requirements, distribution, and polymorphy is wanted.

2. Acaena Sanguisorbae Vahl. var. viridior Cockayne.

South Island: (1.) Sounds Subdistrict of Ruahine-Cook Botanical District—Near the Nelson City waterworks: L. C. (2.) North-eastern Botanical District—In the Kaikoura neighbourhood: A. Wall!

Most likely this well-marked variety is of wide distribution, but so far it has not been recorded to the north of the neighbourhood of the city of Wellington or to the south of Banks Peninsula.

3. Angelica geniculata (Forst. f.) Hook. f.

South Island: Eastern Botanical District—(1.) On rock, Malvern Hills: A. Wall! (2.) On limestone rock at junction of the River Porter and the Broken River, Trelissick Basin: A. Wall!

This species has now been reported far inland in various parts of New Zealand, and can no longer rank as a special coastal plant.

4. Apium prostratum Labill. var.

South Island: Eastern Botanical District—By side of stream on wet bank near Scargill, Canterbury, at about seven miles from the sea. A. Wall and L. C.

5. Asperula perpusilla Hook. f.

North Island: Volcanic Plateau Botanical District—Tall tussock grassland ("grass-steppe" of my *Report on a Botanical Survey of the Tongariro National Park*), Waimarino Plain. H. Carse.

6. Asplenium Colensoi Hook. f.

North Island: Ruahine-Cook Botanical District—Common on moist shady banks near streams in forest of Mount Crowsnest, Wellington. L. C.

7. Carex dipsacea Berggren.

North Island: Volcanic Plateau Botanical District—By the roadside, Waimarino. H. Carse.

8. Carex Solandri Boott.

North Island: Volcanic Plateau Botanical District—Margin of forest, Waimarino. H. Carse.

9. Carmichaelia grandiflora Hook. f.

South Island: Eastern Botanical District—(1.) Mount Torlesse: A. Wall! (2.) Mount Hutt: A. Wall!

Professor Wall's specimens were too small for me to refer them to the special variety of the species to which they belonged.

10. Celmisia Armstrongii Petrie.

South Island: Western Botanical District—Mount Tuhua, in herb-field, subalpine. J. E. Holloway!

Mount Tuhua is a peak, 1,093 m. high, situated to the east of Lake Kaniare, near Hokitika, and distant from the sea about fifteen miles. Its flora was unknown until the Rev. Dr. Holloway sent me a small collection of plants collected by him mostly above the forest-line. This collection shows the flora to be much the same as that at similar altitudes on the actual Divide.

11. Celmisia intermedia Petrie.

South Island: Western Botanical District—Mount Tuhua, in herb-field, subalpine. J. E. Holloway!

12. Claytonia australasica Hook. f.

South Island: Western Botanical District—Styx Valley. J. E. Holloway!

13. Coprosma foetidissima Forst.

North Island: Ruahine-Cook Botanical District—Near Makerua Railway-station, on sandstone bluff. L. C.

14. Coprosma serrulata Hook. f.

South Island: Western Botanical District—Browning's Pass. J. E. Holloway!

15. Corallospartium crassicaule (Hook. f.) J. B. Armstg.

South Island: Eastern Botanical District—Mount Hutt, subalpine. A. Wall!

16. Donatia novae-zelandiae Hook. f.

South Island: Western Botanical District—Mount Tuhua, subalpine. J. E. Holloway!

17. Dracophyllum Kirkii Berggren.

South Island: Western Botanical District—Browning's Pass. J. E. Holloway!

18. Drapetes villosa (Berggren) Cheesem.

South Island: Western Botanical District—Mount Tuhua, subalpine. J. E. Holloway!

19. Epilobium chionanthum Hausskn.

South Island: Eastern Botanical District—Swamp on Waimakariri River bed, on the Craigieburn Run. A. Wall!

20. Euphrasia cuneata Forst. f.

North Island: Ruahine-Cook Botanical District—(1.) Near Plimmerton, in a remarkable subassociation of a *Typha-Phormium* swamp where *Leptocarpus simplex* is dominant: L. C. (2.) Waikanae, on *Sphagnum*: W. H. Field.

21. Forstera Bidwillii Hook. f.

South Island: Western Botanical District—Mount Tuhua, subalpine. J. E. Holloway!

22. Gaultheria perplexa T. Kirk.

South Island: Eastern Botanical District—Near the Rakaia Gorge. A. Wall!

23. Gentiana serotina Cockayne.

South Island: Eastern Botanical District—Hills near "The Point," Rakaia Gorge. A. Wall!

24. Gleichenia Cunninghamii Heward.

South Island: Eastern Botanical District—Forest at base of Mount Hutt. A. Wall!

The localities previously known for this fern in the Eastern Botanical District are: Mount Peel; Alford Forest; Banks Peninsula, especially near Port Levy (T. H. Potts, *Out in the Open*, p. 53, 1882).

25. Isotoma fluviatilis (R. Br.) F. von Muell.

South Island: (1.) Eastern Botanical District—Shore of Lake Rubicon, Mount Torlesse: A. Wall! (2.) North-eastern Botanical District—Awatere River basin, subalpine: C. E. Foweraker and L. C.

This species, first recorded for New Zealand in the *Manual*, p. 401, is now known to occur in all the botanical districts of the South Island excepting the Western and Fiord Districts.

26. Lobelia anceps L. f.

North Island: Ruahine-Cook Botanical District—On drained ground of the Makurerua Swamp, but apparently not common. L. C.

27. Lycopodium cernuum L.

South Island: North-western Botanical District—Near Westhaven (West Wanganui). B. C. Aston!

This discovery of Mr. Aston's is of considerable phytogeographical importance, since it extends the southern range of *L. cernuum* from the neighbourhood of Lake Taupo (Volcanic Plateau Botanical District) for a distance of about eighty-four miles. It also adds another species to the following remarkable list of plants which occur in the North-western Botanical District, but which otherwise are confined to the Northern Botanical Province or extend only a short distance beyond its southern boundary: *Astelia Banksii*, *Adiantum aethiopicum*, *Blechnum Fraseri*, *Dracophyllum latifolium*, *Schoenus tendo*, and *Pterostylis puberula*.

28. Lygodium articulatum A. Rich.

North Island: Volcanic Plateau Botanical District—In forest, Waimarino; apparently rare. H. Carse.

The *Manual* gives the Bay of Plenty and Kawhia as the southern limits of this fern. The above record extends its southern range considerably.

29. Metrosideros lucida (Forst. f.) A. Rich.

South Island: Eastern Botanical District—In patches of forest in gullies on hills near "The Point," Rakaia Gorge. A. Wall!

30. Myosotis Townsoni Cheesem.

South Island: Western Botanical District—Browning's Pass. J. E. Holloway!

This well-marked species has hitherto been recorded only from the Brunner Range and Lyell Mountains, in the North-western Botanical District; its known range is thus extended about sixty miles to the south.

31. Notospartium torulosum T. Kirk.

South Island: Eastern Botanical District—In the vicinity of the Rakaia Gorge. A. Wall!

I have only a mere scrap, but it seems identical with Kirk's type. The species has now been recorded from the above locality, from Mount Peel (where it was recently rediscovered by Mr. R. M. Laing, B.Sc.), the Waikari Hills, the Hanmer Plains area, and the vicinity of the River Mason. Mr. D. Petrie, M.A., suggested to me some time ago that the Clarence Valley plant discovered by Mr. Aston was possibly neither the above nor *Notospartium Carmichaeliae*; and he may quite well be right, as its much-swollen pod looks very distinct.

32. Olearia Colensoi Hook. f.

South Island: Western Botanical District—Mount Tuhua; an important member of the subalpine scrub. J. E. Holloway!

33. **Ourisia macrocarpa** Hook. var. **calycina** (Col.) Cockayne.

South Island: Western Botanical District—Mount Tuhua, in herb-field. J. E. Holloway!

This variety has been recorded by Mr. D. L. Poppelwell from as far south as the mountains near the Haast Pass, but its exact southern limit—*i.e.*, where it is replaced by var. *cordata* (the type of the species)—is not yet known.

34. **Plagianthus cymosus** T. Kirk.

South Island: South Otago Botanical District—Banks of Waihopai Stream, near Invercargill. J. Crosby Smith!

As Mr. Crosby Smith's record of this interesting plant in his list of Southland plants (*Trans. N.Z. Inst.*, vol. 46, p. 223, 1914) may be easily overlooked, I am calling attention to this station.

35. **Pseudopanax lineare** (Hook. f.) C. Koch.

South Island: Western Botanical District—In subalpine scrub of Mount Tuhua. J. E. Holloway!

36. **Ranunculus chordorhizos** Hook. f.

South Island: Eastern Botanical District—Mount Hutt, on subalpine shingle-slip. A. Wall!

37. **Ranunculus Enysii** T. Kirk.

South Island: Eastern Botanical District—Mount St. Bernard. H. Wall!

R. Enysii, according to the *Manual*, is said to occur not only in the Waimakariri River basin, but also, without there being any stations intermediate, on the East Taieri Hills (South Otago Botanical District) and near Lake Harris (Fiord Botanical District). The Taieri station is given on the authority of Buchanan, his *Ranunculus tenuis* from that locality being considered by Cheeseman as a form of *R. Enysii* with the leaves more pinnately divided than usual. But *R. tenuis* Buch. includes not only the Taieri plant but one from Masterton (Ruahine-Cook Botanical District), while the figure (*Trans. N.Z. Inst.*, vol. 20, pl. xii, 1888) does not match any form of *R. Enysii* from its original habitat; therefore I think the Taieri habitat should not be accepted. I would also exclude the Lake Harris and Masterton (probably Tararua Mountains) habitats. Should it eventually be proved that I am right, then the species under consideration is, on our present knowledge, confined to the Waimakariri River basin and to the south-eastern portion of the Hurunui River basin, where Professor Wall recently collected it.

Two very distinct forms of the species were collected by Wall on Mount St. Bernard, and I have also in my herbarium and garden several well-marked forms, but I await cultivation tests before going into the matter of varieties in this rather puzzling aggregate species.

J. B. Armstrong (*Trans. N.Z. Inst.*, vol. 12, p. 336, 1880) includes *Ranunculus geraniifolius* Hook. f. in his catalogue of the plants of Canterbury, but is seems almost certain that the plant he had in mind was *R. Enysii*, to which *R. geraniifolius* bears no small resemblance.

38. Ranunculus insignis Hook. f.

North Island: Volcanic Plateau Botanical District—Mount Ngauruhoe, on wet lava cliffs. H. Carse.

This species is not mentioned in my *Report on a Botanical Survey of the Tongariro National Park*, but it has since been noted by Mr. Allison, of Wanganui, on the south-eastern side of Ruapehu; by Mr. E. Phillips Turner in the bed of the Maungaturuturu River; and by Mr. Carse as above. All the same, it appears to be an uncommon plant for the central group of volcanoes in general and the adjacent part of the Volcanic Plateau.

39. Raoulia glabra Hook. f.

North Island: Ruahine-Cook Botanical District—On summit and other stony exposed places on the Kaukau Range. L. C.

In Aston's catalogue of Wellington plants (*Trans. N.Z. Inst.*, vol. 43, p. 235, 1911) the only localities given for *R. glabra* are the Rimutaka and Tararua Mountains.

40. Rubus parvus Buchanan.

South Island: Western Botanical District—Styx and Arahura Valleys. J. E. Holloway!

In the *Manual* the Taramakau Valley is given as the southern limit of *Rubus parvus*. It is, however, now known to extend almost to the Fox Glacier, and probably it extends still farther to the south. It appears, indeed, to be fairly common on old river-bed, though perhaps somewhat local, throughout the North-western and Western Botanical Districts. Poppelwell does not record its occurrence in the neighbourhood of the Haast Pass or the River Haast.

41. Scirpus inundatus Poir. var.

North Island: Volcanic Plateau—Wet ground on Waimarino Plain. H. Carse.

42. Selliera radicans Cav.

South Island: Eastern Botanical District—(1.) Near the junction of the Porter River and the Broken River, Trelissick Basin: A. Wall! (2.) On the shores of certain of the small lakes (Marymere, &c.) and the slopes adjacent, near Mount St. Bernard: A. Wall!

The *Manual* gives only quite general information regarding the inland distribution of this extremely common coastal plant. Aston (*loc. cit.*, p. 236) states that it ascends to 3,500 ft. on the Kaimanawa Mountains. Petrie records it (*Trans. N.Z. Inst.*, vol. 28, p. 565, 1896) as "rare inland [Otago] and much reduced in size, as at Lakes Wanaka and Te Anau. Ascends to 1,000 ft."; and the *Manual*, p. 395, "ascending to over 2,500 ft. at the base of Ruapehu." Wall's specimens agree with Petrie's remarks as to reduction in size.

43. Urtica ferox Forst. f.

North Island: Volcanic Plateau Botanical District—On bank of river, Makatote Gorge. H. Carse.

44. **Urtica linearifolia** (Hook. f.) Cockayne.

North Island: Ruahine-Cook Botanical District—Makurerua Swamp, where drained, climbing over shrubs. L. C.

45. **Veronica amplexicaulis** J. B. Armstg.

South Island: Eastern Botanical District—Mount Peel, subalpine. H. H. Allan!

Previously I have only known this species from the cultivated plants in the Christchurch Botanical Gardens, which were probably cuttings from the original plant. Also, in the *Manual* Armstrong's original habitat, "Upper Rangitata," is the only one given. Mr. Allan's specimens have not yet bloomed in my garden, but they seem to match exactly the not-readily-mistaken vegetative form of *V. amplexicaulis*, of which I have also a cultivated example.

46. **Veronica Haastii** Hook. f. var. **macrocalyx** (J. B. Armstg.) Cheesem.

South Island: Western Botanical District—Browning's Pass neighbourhood. J. E. Holloway!

I am inclined to think it would be better to treat this variety as a species. If not, then *V. epacridea* should also be united to *V. Haastii*. The plant in question has so far been recorded only from Mount Rolleston, the vicinity of the Waimakariri glaciers, the Rangitata Valley, and the above locality.

ART. XVIII.—*A Note on the Young Stages of* Astraea heliotropium *(Martyn).*

By Miss M. K. MESTAYER.

Communicated by R. L. Mestayer, M.Inst.C.E.

[*Read before the Wellington Philosophical Society, 12th December, 1917; received by Editors, 31st December, 1917; issued separately, 30th May, 1918.*]

IN his "A Commentary on Suter's *Manual of the New Zealand Mollusca*"* Iredale makes the following statement on page 444: "My disposition of the species ranked by Suter in the families Liotiidae, Vitrinellidae, and Cyclostrematidae are as follows: "Transfer *Liotia serrata* Suter, 1908, and *Liotia solitaria* Suter, 1908, to the genus *Angaria* Bolten, 1798, in the family Trochidae," &c.; and on page 439 of the same volume, speaking of the genus *Angaria* Bolten, he says, "This genus has not yet been recorded from New Zealand, though I have recorded two species at the Kermadec Islands. . . . The two species, *Liotia serrata* Suter, 1908, and *Liotia solitaria* Suter, 1908, are probably both juveniles of this genus: the latter certainly is, whilst the species Suter compared it with—viz., *L. stellaris* Ad. & Rve.—is also a juvenile *Angaria*, as is shown here in the British Museum, the type being so placed when it was described."

I have a number of specimens dredged by Captain Bollons from various localities which show very clearly that Iredale was mistaken in transferring

* *Trans. N.Z. Inst.*, vol. 47, p. 417–508, 1915.

Liotia solitaria Suter to the Trochidae, as it is undoubtedly a juvenile Turbinidae, belonging to the genus *Astraea* Bolten, 1798—it being, in fact, the juvenile of *Astraea heliotropium* (Martyn).

In the *Manual of the New Zealand Mollusca*, 1914, Suter records *Astraea heliotropium* (Martyn) as occurring from the Bay of Islands to Stewart Island—that is, practically all round the New Zealand coast. It has been obtained alive in Wellington Harbour, and is plentiful at Kapiti Island. From a dredging off Cuvier Island in 38 fathoms I obtained two specimens, of which Mr. Suter says, "No doubt the embryonic shells of *Astraea heliotropium* (Martyn). Identical with my unfortunate *Liotia solitaria*." From near the Hen and Chicken Islands, in the Hauraki Gulf, in about 30 fathoms, a minute specimen, of 0·5 mm., without spines, was obtained, which Mr. Hedley said was the embyro of an *Astraea*, and it is identical with the protoconchs of the Cuvier Island specimens. Then, from off Channel Island, in Hauraki Gulf, 26 fathoms, five specimens were obtained, measuring 1·5 mm., 2 mm., 2·5 mm., 3 mm., and 4 mm. diameter—all specifically identical with the Cuvier Island specimens. On the last spine of the largest specimen the adult sculpture of *Astraea heliotropium* is just beginning to show. Unfortunately, it is rather damaged and water-worn.

A dredging off Chetwode Island, Cook Strait, 55 fathoms, gave two young *Astraea heliotropium* (Martyn), of 18 mm. and 19 mm. diameter, so far developed as to be quite unmistakable; and two smaller ones, of 5 mm. and 3·5 mm., the larger of which is much broken, though enough remains to identify it with the larger ones, while it at the same time shows most clearly its specific identity with the smallest, which is specifically identical with the northern specimens. The smallest (3·5 mm.) has only three whorls, and a wide umbilicus, within which all the whorls are clearly visible. The upper surface is very slightly concave, the whorls coiled almost in one plane; colour white, the interior of the lip slightly nacreous. The largest specimen has the protoconch sufficiently distinct to establish the specific identity of the smallest.

Mr. J. C. Andersen collected three young specimens of *Astraea heliotropium* (Martyn) on the beach of Kapiti Island—good examples, 30 mm., 34 mm., and 40 mm. In all three the protoconch is unusually clean, and under a powerful pocket-lens the embryonic shell is clearly visible; while the largest one is particularly useful as exhibiting the gradual development of the spines, the change from the depressed discoidal spire of the juvenile to the somewhat raised spire of the adult; and the gradual increase of the at-first nodulous spiral ribs, which when the shell reaches a diameter of about 25 mm. change to close sharp growth lamellae on the spirals. These three specimens are in the reference collection in the Dominion Museum, Wellington.

From dredgings in Dusky Sound I have a series of seven, of which four are quite minute and the other three are unmistakable young *Astraea heliotropium* (Martyn), 20 mm., 19 mm., and 13 mm. diameter, with clean spires which show the embryos very well. This is perhaps the best locality for this species.

If all these specimens were mixed together it would be an absolute impossibility to be sure of the locality of any single specimen. Specimens illustrating this change from juvenile to adult have been placed in the Dominion Museum.

ART. XIX.—*On Mosquito Larvicides.*

By H. B. KIRK, M.A., Professor of Biology, Victoria University College.

[*Read before the Wellington Philosophical Society, 25th July, 1917; received by Editors, 31st December, 1917; issued separately, 10th June, 1918.*]

IN connection with work that has been entrusted to me in some of the military camps in the matter of fly-control it has been necessary to investigate the effectiveness of various substances as killing agents. Incidentally, the matter of larvicides for mosquitoes came under investigation. This year the New Zealand Institute has set aside a sum of £25 from the Government research grant, which sum may be drawn upon in refund of actual expenses in investigating and experimenting in this direction. The present paper deals mainly with the relative value of certain mosquito larvicides. The experiments have been made mainly with the larvae of various species of *Culex* found in New Zealand and with the larvae of a culicine mosquito found often in brackish water on the coast near Wellington. As there is probably a real danger that *Anopheles* or other harmful forms may at any time be introduced into New Zealand, it is advisable that methods of extermination should be as effective as possible. I hope to be able shortly to make some contribution to our knowledge of the best means of dealing with adult mosquitoes.

The work that has been done in the Panama Canal zone under Gorgas, at Khartoum under Balfour, and in other places where disease-bearing mosquitoes occur is well known. Larvae are generally dealt with by means of a film that prevents their breathing when they come to the surface, or by use of a lethal agent that diffuses evenly throughout the water. The substance used as a film is generally crude petroleum. One of the best-known direct lethal agents is an emulsion of crude carbolic acid.

In *Notes on Fly-control in Military Camps*, issued last year by the Defence Department, I called attention to the value of light oil* as a killing agent. It is sprayed in mixture or in emulsion with 3 or 4 parts of water, and is very fatal to maggots and to adult flies. It has to be applied in greater strength to kill fly-pupae. Experiments with light oil as a mosquito larvicide show that it is a most valuable substance, whether used as a film or as an emulsion.

The question whether it is best to use a film or an emulsion depends upon several considerations. Of these, the relation of volume of water to surface may be important. This is, however, a consideration of economy or of ease of treatment. A consideration of actual efficiency is the exposure of the surface to wind. If a surface is wind-swept a film is broken very quickly. Certain experiments in toughening the films will be referred to later. In certain cases it may be best to use both film and emulsion, especially if many pupae are present, these being less easily killed by the emulsion than are the younger larvae.

Light oil makes a film that spreads more rapidly than crude petroleum; its colour enables the operator to see at a glance whether the film is complete: it is very fatal to insects, and a larva thrusting the breathing-siphon

* "Light oil" is the lowest of the three great fractions into which the distillation products of coal-tar are first broken, and it comprises those constituents that have a boiling-point up to about 200° or 210° C. The two higher fractions are known as "medium oil" and "heavy oil" respectively.

into the film is paralysed and seldom comes again to the surface. Dishes of equal size, 2 ft. by 1 ft. 3 in., containing the same quantity of water and the same number of larvae at the same stage, have been treated, one with light oil, the other with crude petroleum in like amount. In all experiments—and I have repeated them over a dozen times—the larvae under the film of light oil have been dead or helpless on the bottom within fifteen minutes, while in the petroleum dish some have been active after an hour or more. In view of the possible breaking of films, comparative rapidity of action is a matter of great importance. The experiments referred to have been repeated on the large scale on pools in various parts of the North Island, and the laboratory results have been amply confirmed.

The film is best produced by spraying the pool, but the oil may be sprinkled from a bottle or other vessel, or a leafy twig may be dipped in it and shaken over the water. In choosing a spraying instrument for light oil it is necessary to choose one without rubber tubing, as some constituents of light oil are solvents of rubber.

Experiments with regard to the toughening of films to render them less easily broken are now being made. Up to the present I have found nothing better than raw linseed-oil. It should be shaken up well with the light oil before being applied. I am not yet sure that the advantage gained is sufficient to justify a strong advocacy of its use; but it certainly does make a film more resistant.

In testing the killing-power of crude carbolic acid I have taken the formula for the emulsion from the report of the Wellcome Laboratory at Khartoum for 1911, p. 109, where directions sent from Panama are quoted: "Crude carbolic acid* containing about 15 per cent. phenol is heated to 212° F., finely pulverized resin is added, and the mixture kept boiling until the resin is all dissolved. Caustic soda is then added, and the mixture kept at 212° F., for about ten minutes, or until a perfectly dark emulsion without sediment is obtained. The mixture is thoroughly stirred from the time the resin is added until the end." It is stated that 1 part of this mixture in 5,000 parts of water containing mosquito-larvae will kill all the larvae within five minutes. If it is used in the proportion of 1 to 8,000 the larvae are killed in thirty minutes. In my experiments I was unable to obtain results as good as these. I obtained, however, much better results when using an emulsion of light oil.

The experiments tabulated below are only a few of a very long series, and all have been verified by actual work at normally infested pools in the open. With regard to various entries in the table I may make the following explanation:—

In the column headed "Twitching" is noted the time at which the larvae were first observed to be all motionless or twitching helplessly at the bottom of the vessel. This is for all practical purposes the time of death, as the larvae do not recover from this condition unless removed to fresh water. Time of actual death is, however, of importance in view of the fact that mosquitoes sometimes breed in slowly flowing water.

In the column "Apparently dead" is entered the time at which response could not be obtained to weak induction shocks.

* A fine account of the efficacy of crude carbolic acid and other larvicides is given by Howard, Dyar, and Knab in *The Mosquitoes of North and Central America and the West Indies*, vol. i, pp. 379 *et seq.*, Carnegie Inst., Washington, 1912.

In the column " Dead " is noted the time at which removal to abundant fresh water was made in cases where this removal did not bring about at least temporary recovery. For this purpose I regarded proof of death as sufficient if no movement of any kind took place within twenty-four hours.

No very young larvae were used in these experiments.

Emulsion.	Strength.	Number of Larvae.	Time.	Larvae observed to be				Remarks.
				Active.	Twitching.	Apparently Dead.	Dead.	
Carbolic	1/4,000	3	5 p.m.	6 p.m.	7.30 p.m.	9 p.m.	..	Recover in fresh water.
,,	1/8,000	3	6.25 p.m.	7.25 p.m.	..	11.30 p.m.	..	,,
,,	1/16,000	3	6.30 p.m.	3 days later	..	4 days later	..	One recovers in fresh water.
Cresolia	1/4,000	3	3.40 p.m.	..	..	4.20 p.m.	4.20 p.m.	Dead in 40 minutes.
,,	1/8,000	2	3.50 p.m.	..	4.30 p.m.	6.20 p.m.	6.20 p.m.	Dead in 2 hours 30 minutes.
Light oil	1/4,000	*2	4.50 p.m.	..	..	4.52 p.m.	4.52 p.m.	Dead in 2 minutes.
,,	1/8,000	6	3.15 p.m.	..	3.22 p.m.	3.55 p.m.	3.55 p.m.	Dead in 40 minutes.
,,	1/16,000	*6	2.50 p.m.	2.52 p.m.	3 p.m.	7 p.m.	7 p.m.	No observation between 3 p.m. and 7 p.m. Dead *within* 4 hours 10 minutes.
,,	1/32,000	6	2.50 p.m.	3 p.m.	7 p.m.	2 p.m. next day	..	No observation between 7 p.m. and 2.52 p.m. next day. Dead *within* 24 hrs.

* One of these was a pupa.

Many other substances, including well-known disinfectants and plant-sprays, were used, but with no results worth publishing. Sulphates of iron and of copper, potassium ferrocyanide, and other well-known substances gave, in the dilution of 1 in 4,000, negligible results.

From the above table it will be seen that when there is no access of fresh water an emulsion of light oil may be used in the proportion of 1 in 32,000. The emulsion that will give this result must, of course, be one that contains nearly all the light oil that the emulsionizing agent can carry and that has no needless water. The formulae here given, chosen from a number that have been arrived at, may be relied upon :—

(1.)	Soft-soap	100 parts.
	Light oil	440 ,,
	Water	100 ,,
	Caustic soda	80 ,,

It is best to add the light oil after the other substances have been heated together to a temperature of 100° C.

This is a thick jelly, and may be diluted with water to liquefy it.

(2.)	Soft-soap	20 parts.
	Light oil	50 ,,

A thick jelly-like soap.

Where transport was not an important consideration the desired amount of water to make these emulsions liquid would usually be added when they were being made.

(3.)	Castor-oil	50 parts.
	Caustic soda (sat. solution of 98 per cent. caustic soda)	15 ,,
	Water	20 ,,
	Light oil	170 ,,

It is best first to make a soap by boiling the castor-oil and the caustic-soda solution. When an even yellow-green soap is formed the light oil may be added. Constant stirring is, of course, necessary whichever formula is used.

As is well known, potash is generally more suitable than soda, but its greater cost makes it unsuitable for this purpose. Owing to a shortage of potash, soft-soap is becoming costly, and therefore other emulsionizing agents are being experimented with. Up to the present good results have been got with resin, neatsfoot-oil and whale-oil. The last-named is the cheapest, and will be used for work in military camps. Unfortunately, it is sometimes difficult to saponify it by the means always available.

The castor-oil emulsion referred to above is a clear liquid emulsion, and keeps well.

ART. XX.—*On the Age of the Waikouaiti Sandstone, Otago, New Zealand.*

By J. ALLAN THOMSON, M.A., D.Sc., F.G.S., Director of the Dominion Museum, Wellington, New Zealand.

[*Received by Editors, 31st December, 1917; issued separately, 10th June, 1918.*]

ALTHOUGH contradictory opinions were held by Hutton and Haast on the one hand, and Cox, McKay, and Hector on the other, as to the relative age and relationships of the Notocene rocks of the north and south sides of the Shag River, all these geologists were in agreement in correlating the Waikouaiti sandstone on the one hand with the Caversham sandstone, and on the other with the Ototara limestone. Both these correlations were accepted also by Park (1910); but it is necessary to remember that at that time he placed the Ototara stone as the uppermost member of the Oamaruian. Marshall, in 1906, did not attempt a more detailed correlation than that the Caversham sandstone belonged to the Oamaru system, but in 1916 he referred to the foraminiferal limestone at Sandymount, which he had previously correlated with the Caversham sandstone, as a representative of the younger limestone of New Zealand—*i.e.*, Ototaran. Thus practically all geologists who have written on the subject have agreed that the Caversham sandstone and Waikouaiti sandstone are the same horizon and are Ototaran.

The rightness or wrongness of this conclusion has more than a merely local interest, for on it hang two other questions of a more general nature. First, the age of the Dunedin volcanic series can only be limited as regarding its commencement by reference to the Caversham sandstone—until a detailed palaeobotanical investigation of the intervening Fraser's Gully plant-beds is available. Secondly, the Miocene age of the Oamaruian is based very largely upon Chapman's conclusions regarding the Foraminifera collected by Park from the clays underlying the Waikouaiti sandstone, and if the latter is Ototaran the clays are lower Ototaran, or more probably Waiarekan, and the Middle, or more probably Lower Oamaruian, is Miocene. Opinions to the contrary, however, have recently been independently expressed by Marshall and myself (1917). Discussing the Hampden beds, I stated that "the percentage of Recent species in the Waiarekan is not inconsistent with an older age than Miocene for this stage," while Marshall concluded that "these Onekakara [*i.e.*, Hampden] beds seem to be more rightly classed with the Eocene than with any other European system."

Obviously, then, if Chapman's correlation of the clays of Waikouaiti with the Miocene is admitted, either (*a*) the lower Ototaran or Waiarekan is Miocene, and the opinions stated by Marshall and myself err in ascribing too great an age to the Waiarekan, or (*b*) the Waikouaiti sandstone is not Ototaran.

During a visit to Waikouaiti at Easter, 1917, in company with Professors J. Park and W. N. Benson, of Otago University, I collected from the Waikouaiti sandstone at the North Head a number of brachiopods, of which seventeen were referable to *Pachymagas abnormis* Thomson, while the remaining three belonged to a small species of *Pachymagas* with mesothyrid foramen, probably nearly related to the more orbicular forms of *P. parki* which occur in the Hutchinsonian of All Day Bay.

Pachymagas abnormis was one of the species which I adduced in 1917 as evidence of the Upper Oamaruian age of the beds in the Takaka Valley, and subsequent discoveries have not invalidated its usefulness in this respect. I have since collected it in the uppermost bed of the Mount Brown limestone at the foot of the dip slope of the cuesta opposite Weka Pass—*i.e.*, at a slightly higher horizon than the holotype, but still probably Hutchinsonian—and a single specimen in the Hutchinsonian greensands of All Day Bay. It occurs abundantly in the Awamoan mudstones of All Day Bay, and thus ranges in the Oamaru district from Hutchinsonian to Awamoan, but has not been found in the Ototaran. Now, a larger number of species are known from the Ototaran of the Oamaru district than from any other stage in any locality in New Zealand, so we are quite justified on the present evidence in considering *P. abnormis* a purely Upper Oamaruian species.

Mr. S. S. Buckman, of Thame, England, has suggested in correspondence that *Pachymagas abnormis* should not be referred to *Pachymagas*, but should be made the type of a new genus on account of its beak characters, and if this course is followed it would be possible to differentiate a number of species within the somewhat variable series I have referred to *P. abnormis*. The specimens from the Awamoan mudstones of All Day Bay and from the Waikouaiti sandstone would, however, still have to be retained in the same species.

The conclusion to be drawn from the presence of this brachiopod, then, is that the Waikouaiti sandstone is not Ototaran (*i.e.*, Middle Oamaruian), but Upper Oamaruian, and it may well be Awamoan, and the underlying clays Hutchinsonian. In this connection an examination of the brachiopods from the sandstone at Seacliff, and from the Caversham sandstone and the greensands underlying the latter rock at the back of Flagstaff, would be of considerable interest, and I should be glad to receive specimens from these localities.

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Art. XXI.—*On the Distribution of* Senecio saxifragoides *Hook. f.* *and its Relation to* Senecio lagopus *Raoul.*

By Professor A. Wall, M.A.

Communicated by R. Speight, M.Sc.

[*Read before the Philosophical Institute of Canterbury, 5th December, 1917; received by Editors, 31st December, 1917; issued separately, 10th June, 1918.*]

Plates XI–XIII.

1. Introduction.

(*a.*) *General.*

The problem to be attacked in this paper is suggested in the following passage from L. Cockayne ("Notes on the Plant Covering of Kennedy's Bush and other Scenic Reserves of the Port Hills," *Report on Scenery Preservation*, Parliamentary Paper C.–6, 1915) concerning *S. saxifragoides*: "It also is a most striking plant. Now, an almost identical species, named *Senecio lagopus*, also occurs on the main mass of Banks Peninsula, which differs from *S. saxifragoides* merely in the possession of numerous bristles on the leaf, whereas in the latter such are absent. Yet, so far as is known, *S. lagopus* does not occur on the Port Hills, nor *S. saxifragoides* on Banks Peninsula proper. If this is truly a fact, the distribution of these two species, each equally well suited to the rock-conditions of the area, is one of the most remarkable cases of plant-distribution in the world."

The same authority, in his description of his new species, *Senecio southlandicus* (*Trans. N.Z. Inst.*, vol. 47, p. 118, 1915), further says, "The species is, indeed, far more distinct from *S. bellidioides* and *S. lagopus* than are these from one another. The classification of the whole series, including those already mentioned, together with *S. saxifragoides* Hook. f. and *S. Haastii* Hook. f., is in a most unsatisfactory position. Specimens are constantly coming to me from various correspondents which it is impossible to place with any degree of satisfaction. There are undoubtedly a number of well-marked forms, which demand, at the least, varietal names. Even one fixed character may serve quite well as a specific mark. This is illustrated in the case of *S. saxifragoides* and *S. lagopus* (the type from Akaroa), where the presence of numerous bristles, or their absence, on the upper surface of the leaf is the sole distinguishing character, so that, so far as large plants of the two are concerned, if this character were not present no one could consider them in any degree different."

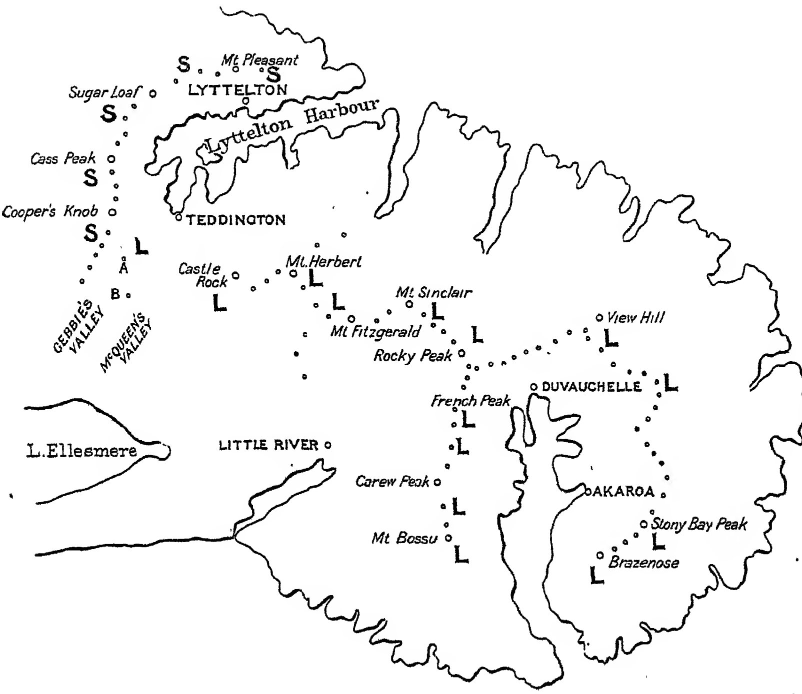
In this paper attention has been directed to these two species solely as they occur on Banks Peninsula.

Banks Peninsula is situated in lat. 43° 32′ S. and long. 175° 30′ E., and forms a rough elliptical salient on the east coast of the South Island of New Zealand. Its diameter in a N.W.–S.E. direction is about twenty-five miles, and its breadth at right angles thereto about eighteen miles. Some forty miles to the westward stretches the main chain of the Southern Alps, from which the peninsula is separated by the gently inclined expanse of the Canterbury Plains, so that it is almost as completely isolated as regards the distribution of subalpine vegetation as if it had been separated from the mountain region by the sea.

The oldest rocks within its limits consist of Trias-Jura sedimentaries overlain in places by a thin veneer of Cretaceous rhyolites, but the main

Photographic reproduction of relief map of Banks Peninsula, from original in Canterbury Museum by S. C. Farr.

mass of the peninsula was built up in mid-Tertiary times by flows of basalt and fragmentary material of similar lithological character, poured out from two vents situated somewhere near the centres of Akaroa and Lyttelton Harbours. A third focus of activity lay near Mount Herbert (3,012 ft.), but it was of less importance, although it was responsible for the formation of the highest peak in the area. The high cones thus formed were subject to paroxysmal explosions of moderate intensity, and their surface was modified by the establishment on their outer slopes of a well-developed system of radiating valleys. Volcanic action ceased in all probability long before



Map of Banks Peninsula and Port Hills, showing distribution of the two species of *Senecio*. L, *Senecio lagopus*; S, *Senecio saxifragoides*; A, rhyolite escarpment where *S. lagopus* occurs; B, rhyolite escarpment where neither species occurs.

the end of the Tertiary era. After the stream-system had reached a mature stage the land sank, and the sea entered the floors of the enlarged craters and extended a considerable distance up the lower reaches of the valleys, and these now form marked indentations of the coast-line. Owing to the prolonged weathering the land is now covered with a rich and fertile soil, and steep rock-faces occur only on the coast and at higher levels, where the more resistant basalts form at times precipitous cliffs—the characteristic habitat of the senecios under consideration.

The following are the most important geological considerations affecting the distribution and ecological conditions of plants established in the locality:—

(1.) The isolation of the region from neighbouring mountain areas since it was first formed.

(2.) The uniformity of the lavas which form the majority of rocks in the area. No anomalies of distribution can be interpreted in the light of lithological differences in these rocks.

(3.) As a result of prolonged denudation the crater-ring of the Lyttelton volcano has been broken down at its south-western side and a sector completely removed, so that a stretch of comparatively low country, nowhere over 875 ft. in height, and consisting of exposed rhyolites and sedimentaries, separates the northern part of the crater-ring from the other part of the peninsula. This northern part forms the low range usually called the "Port Hills," and is referred to throughout this paper, as the habitat of *Senecio saxifragoides*, by this name.

For a fuller account of the geological features of this area see J. von Haast, *Geology of Canterbury and Westland*, 1879, and R. Speight, "The Geology of Banks Peninsula" (*Trans. N.Z. Inst.*, vol. 49, pp. 365–92, 1917).

(*b.*) *Historical.*

Senecio saxifragoides was first described by Hooker in 1853 (*Flora Novae-Zelandiae*, vol. 1, p. 144), and in the *Handbook* its discovery is accredited to Lyall (*Handbook*, p. 159).

Hooker, Kirk (*Students' Flora*, p. 339), and Cheeseman (*Manual*, p. 372) agree in describing *S. saxifragoides* as distinguished from *S. lagopus* only in respect of the leaf, which is described as "clothed with shining silky and woolly hair" (Hooker), "silky or villous" (Kirk), "silky or villous" (Cheeseman), upon the upper surface only, and wanting the stout bristle which characterizes *S. lagopus* and *S. bellidioides*. Kirk says, "The leaves are often glabrous or glabrate on the upper surface, but never bristly as in *S. lagopus*." Cheeseman says, "A handsome species, separated from large states of *S. lagopus*, some of which approach it very closely, by the much stouter habit, more copious villous hairs, and larger thicker leaves, which are silky above and never show the stout bristly hairs so characteristic of *S. lagopus* and *S. bellidioides*."

All agree that these three species, *S. lagopus*, *S. bellidioides*, and *S. saxifragoides*, are very closely allied. Hooker (*Handbook*) says, "This [*S. lagopus*] and the two following [*i.e.*, *S. bellidioides* and *S. saxifragoides*], though most dissimilar in their usual states, appear to me to be united by intermediate forms," and (*Flora Novae-Zelandiae*), "This and the two following are closely allied and very singular species."

The distribution of *S. saxifragoides* is given by Hooker as "Port Cooper"; by Kirk as "Port Lyttelton, Banks Peninsula"; and by Cheeseman as "Port Lyttelton and other localities on Banks Peninsula."

All agree in describing the leaf of *S. saxifragoides* as broader or more nearly orbicular than that of *S. lagopus*; but they do not quite agree as to the relative size. Hooker makes the leaf of *S. lagopus* 2 in. to 4 in. long (!); that of *S. saxifragoides* 3 in. to 5 in. long. Kirk makes the leaf of *S. lagopus* 1 in. to 8 in. long (excluding the petiole), and that of *S. saxifragoides* 3 in. to 6 in. long. Cheeseman makes the blade of *S. lagopus* 1 in. to 5 in. long, and that of *S. saxifragoides* 3 in. to 6 in. long. Raoul's description of *S. lagopus* (*Choix*, p. 21) gives the leaf about 1 decimetre (4 in.) long and from 7 to 9 centimetres (3–3½ in.) broad. Hooker's and Raoul's descriptions would seem to have been based upon comparatively small specimens of both species.

The distribution of *S. lagopus* is given by all authorities as from the Ruahine Mountains to South Canterbury.

The original description of *S. lagopus* by Raoul, and his plate (*Choix*, pl. 17), must here be referred to, as of the greatest importance in the study of the two species. In describing the petiole of *S. lagopus*, Raoul says, "Petioli . . . canaliculati in vaginam semiamplexicaulem dense lanatam dilatati"; and in describing the leaf he says, "Folia . . . pilis rigidis grossis, spinescentibus praesertim ad margines inspersa." His plate shows a plant with four large and several small leaves. Of the four large leaves three are glabrate (as the old leaves of both *S. lagopus* and *S. saxifragoides* always are): the fourth bears the characteristic "bristles" very thickly close to the margin all round the leaf, or nearly so, and near the apex; less thickly upon the upper third of the leaf or thereabout; the lower part of the leaf bears the hairs only, very thickly distributed. The hairs and bristles occur together over some portions of the leaf, about the middle and towards the apex, but at the apex itself and in its immediate neighbourhood the bristles alone occur. The dual occurrence of hair and bristle* on the same leaf, which no subsequent authority describes at all, will appear to be of great importance to this inquiry; and it may be added that my descriptions of the variant forms of *S. saxifragoides* given below were fully made before I had seen Raoul's plate.

The species are further thus referred to by Laing and Blackwell (*Plants of New Zealand*, pp. 437–38, 1906): "The handsome *S. saxifragoides*, supposed by Kirk to be confined to Banks Peninsula, is undoubtedly the typical *S. lagopus* of Raoul. It still produces its large-leaved rosettes on the southern faces of cliffs, where Raoul found it, near Akaroa. It is also plentiful behind Lyttelton, often growing in altogether inaccessible localities, and it is the only *Senecio* which haunts these situations on the Peninsula."

2. Special Characters of the Two Species under Consideration.

1. All round the margin of the leaf of *S. lagopus*, *S. saxifragoides*, and *S. bellidioides* occur at very regular intervals—*i.e.*, at the ends of the veins—rounded glandular protuberances of a very dark red or purple colour. Microscopical examination shows these to be typical hydathodes.

2. The petiole of the leaf of *S. lagopus* bears quantities of dark-red or purple bristles, generally spotted or pied with white; these are continued up the back of the midrib nearly to the apex of the leaf, and are also present along the margin all round the leaf.

3. *S. saxifragoides* also shows this purple or pied bristle upon the petiole and the back of the midrib exactly as in *S. lagopus*, and also bears this bristle all round the margin of the leaf, making a continuous fringe. The young leaves of *S. saxifragoides* have yellow marginal bristles, which change gradually into purple and continue to deepen in colour up to maturity. The yellow bristle, however, is usually present together with the purple, the yellow being upon the upper surface of the leaf just within the margin, the purple being upon the margin itself; but they are sometimes more or less mixed together.

4. Forms of *Senecio lagopus* and *Senecio saxifragoides* which grow in situations shaded by other vegetation, as among long tussock-grass, or on

* The term "bristle" is kept throughout, as that employed by previous authorities though the organ is really a glandular hair.

the edge of forest, or beneath large plants of *Linum monogynum*, show a complete or almost complete absence of the purple colouring-matter in the glandular hairs, and also tend to be larger, to have a much longer petiole than usual, and to be less thickly covered with silky hairs or bristles (as the case may be) than the usual form.

5. Though the plant of *S. saxifragoides* is probably on the average a little larger than that of *S. lagopus*, the difference is not great. Kirk's measurements do not agree with the others. A leaf of *S. lagopus* 8 in. long without the petiole would be most exceptional, but leaves 6 in. long with a petiole of from 3 in. to 4 in. are common—*e.g.*, on Mount Herbert—and *S. saxifragoides* can hardly ever be much larger than this, though its leaves are generally broader and more substantial. I have a very strong impression, which I hope to verify by future observation, that the plants of *S. lagopus* in the neighbourhood of Akaroa Harbour are in general distinctly smaller than those of the Mount Sinclair to Mount Herbert area. This would explain the small measurements of Raoul's type. Some of the large individuals of the Mount Herbert area, indeed, almost seem to be intermediate states such as Hooker speaks of. The largest leaf of *S. lagopus* measured by me shows the following dimensions: Length of blade, 6 in.; length of petiole, 3 in.; breadth of blade, 4 in. This plant grew on the south-western peak of Mount Herbert, and was exceptionally large. Its measurements equal those of *S. saxifragoides* in any authority and exceed most of them. A most exceptionally large plant of *S. saxifragoides*, however, gave the following measurements: Length of blade, 7½ in.; length of petiole, 4½ in.; breadth of blade, 6¾ in. This is much above the average of the species, the plant being shaded by plants of *Linum monogynum* and tussock-grass.

6. Thus the leaf of typical *S. lagopus* is found to bear six different types of structure—(*a*) The thick brownish "wool" of the rootstock, which covers the base of the petiole and seems to pass gradually into (*b*) long white silky hairs, which clothe the petiole and are continued up into the sinus and on to the lower portion of the leaf; (*c*) the characteristic stout bristle which occurs, as described below, on the margin and upon the upper part of the blade especially; (*d*) the dark-red or purple bristle which is thickly intermixed with the white hairs upon the petiole, from the point where the brownish "wool" passes into white hairs up to the apex, or nearly, on the back of the midrib; (*e*) the glandular marginal purple protuberances; (*f*) the white tomentum upon the back of the leaf.

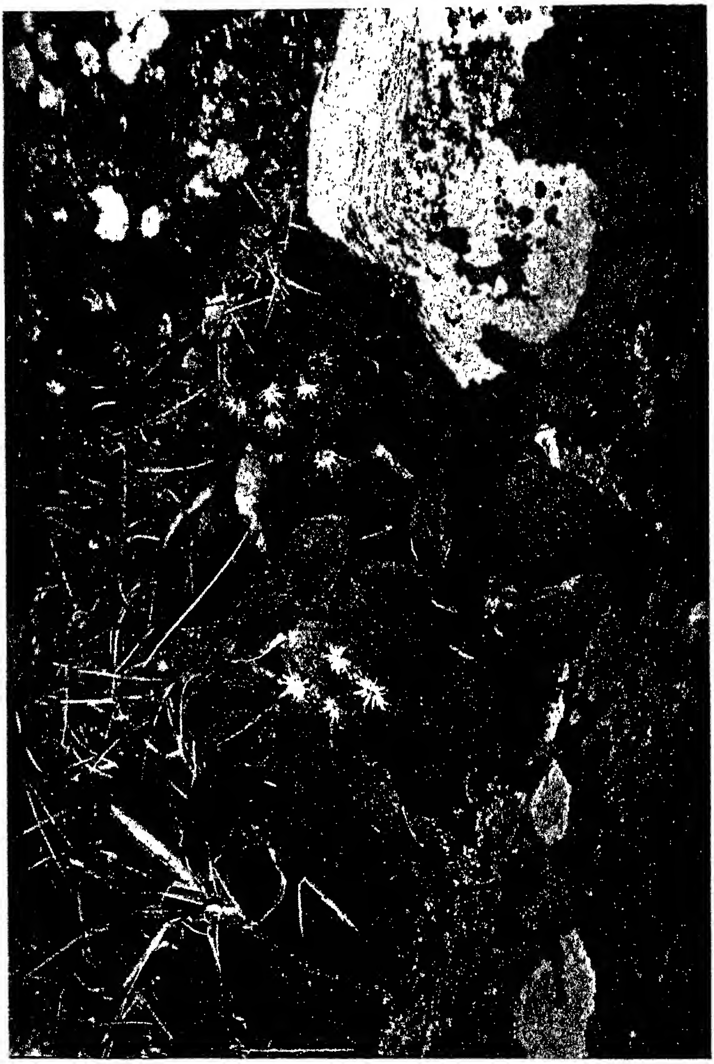
7. Many plants of *S. lagopus* bear the silky hairs as well as the characteristic stout bristles. The silky hairs usually occur very thickly on the petiole and at the base of the leaf and in the immediate vicinity of the midrib; less thickly, if at all, on the rest of the leaf, as depicted in Raoul's plate.

8. Many plants of *S. saxifragoides* bear the stout bristles which have been hitherto considered to be characteristic of *S. lagopus* and *S. bellidioides*. The bristles occur in *S. saxifragoides* under these conditions:—

(*a*.) They occur near the apex of the leaf upon the upper surface of about one-fourth or one-third of the whole—not near the base, and but rarely on the lower half of the leaf at all (as in Raoul's plate of *S. lagopus*), though specimens have been observed with the bristles fairly evenly distributed over the whole surface. (See Plate XII.)

(*b*.) They occur regularly and as a permanent character all round the margin exactly as in *S. lagopus* and *S. bellidioides*.

Young plant of *Senecio saxifragoides*, showing bristles, from Mount Pleasant, Port Hills.



[R. Speight, photo.

Plants of *Senecio lagopus* photographed *in situ* on Mount Sinclair, Banks Peninsula.

(*c.*) They occur sometimes, not infrequently, near the margin, upon the surface of the leaf, to a distance of about $\frac{1}{4}$ in. or $\frac{1}{5}$ in. from the margin all round the leaf, as in Raoul's plate of *S. lagopus*.

(*d.*) They occur most frequently upon small, ill-nourished, or depauperated individuals. They occur more frequently upon the lower and outer leaves than upon the upper and inner leaves. Leaves bearing many bristles have been often found upon plants which are in every other respect typical specimens of *S. saxifragoides;* some whole plants bearing such leaves have been preserved in the collection mentioned below.

The stout bristles may be almost certainly observed upon all individual plants which are found growing alone, apart from the large masses in which they generally cluster, such plants being generally small and unfavourably situated as regards aspect or soil. Many leaves of such plants have been preserved in the collection, and in many cases the bristles are to be seen as thickly congregated, as evenly distributed, and as stout as in typical examples of *S. lagopus* and *S. bellidioides*. Such leaves are, however, all small, much below the average size of the species, but they are from undoubted examples of *S. saxifragoides* which are seedlings from neighbouring masses of quite normal specimens. A small plant of *S. saxifragoides* from Mount Pleasant, Port Hills, which is now under cultivation at Canterbury College, has its leaves thickly and evenly covered with the stout glandular hairs here mentioned, and is in no respect to be distinguished from specimens of *S. lagopus* of the same age. (See Plate XIII.)

9. Microscopical examination of the so-called bristle yielded the following results :—

(*a.*) The bristles are simply typical glandular hairs.

(*b.*) The bristles have exactly the same structure in both species.

(*c.*) The bristles upon the margin of each species differ from those of the blade only in the length of the stalk, except that in the case of *S. saxifragoides* there is a slight difference in colour.

(*d.*) The " silky hairs " of both species have exactly the same structure. The " hair " arises from a single cell, the " bristle " from several.

(*e.*) The glandular organ on the margins of the leaves is a typical hydathode.

(*f.*) The variegated appearance of the bristle is due to the arrangement of the colouring-matter, which is present in some cells, absent in others, with no definite arrangement.

3. DISTRIBUTION ON BANKS PENINSULA.

For the purpose of this study the forms of *Senecio lagopus* were observed on all the chief peaks on both sides of Akaroa Harbour, such as Brasenose, Stony Bay Peak, Mount Bossu, and Carew Peak; then on the principal high points on the ridge connecting the Akaroa Harbour heights with the main mass of Mount Herbert, such as Mount Sinclair and Mount Fitzgerald. These points are all between about 2,500 ft. and 2,700 ft. high. Both peaks of Mount Herbert, 3,000 ft. and 2,800 ft. respectively, were visited on several occasions. Specimen leaves of *S. lagopus* were collected from various points, especially from Mount Herbert, and preserved.

The forms of *Senecio saxifragoides* were next observed, and found to occur on all the peaks of the Port Hills from that south-west of Cooper's

Knob to Mount Pleasant, from all of which specimens were collected. These points are mostly from 1,600 ft. to 1,800 ft. high.

Senecio lagopus was found to occur plentifully in all favourable localities —that is, especially on and about all steep rocks which face south and south-west—practically continuously from the Akaroa Heads, on both sides of Akaroa Harbour, to within a mile of the Port Hills. There is hardly a space of even two miles in extent anywhere along this main line in which *S. lagopus* does not occur; it occupies an almost continuous line between the points mentioned, and does not here differ generally from the form of *S. lagopus* as known elsewhere in New Zealand.

The most rema kable point about this distribution concerns the gap of about four miles, a low undulating neck, which connects the south-west peak of Mount Herbert with the Port Hills. This area is mostly under cultivation, and offers but few escarpments. There are, however, three or four possible localities, rhyolite escarpments or peaks, from 600 ft. to 875 ft. high, chiefly on the northern side of the gap. Upon the highest and most likely of these stations, rocks between Gebbie's and McQueen's Valleys, about 875 ft. high, neither has been found; but upon two of them (about 600 ft. to 700 ft. high), one just north of the road from Teddington to Gebbie's Valley and the other just north of that, *Senecio lagopus* occurs —not plentifully, but undoubted typical *S. lagopus*. Between these two points and Mount Herbert, a distance of about three miles, neither plant is found, the ground being nearly all under cultivation. The northernmost of these points is barely one mile from the nearest peak of the Port Hills, that south of Cooper's Knob (about 1,600 ft. high), and here *S. saxifragoides* begins to appear. This seems to me a most striking and puzzling fact. Upon the peak next again to the south (on the Port Hills), though it offers an ideal locality, neither plant occurs.

We may conjecture that under the original conditions some part of this gap at least was occupied by both species, but at present *S. lagopus* only is found there, and that only upon the northern side, and upon what is virtually a spur of the Port Hills. Mr. R. M. Laing, however, informs me that he has collected plants of *S. saxifragoides* at various points on Banks Peninsula proper, in the neighbourhood of Akaroa, and it has been seen above that both Kirk and Cheeseman give Banks Peninsula as a locality for the species. It may be suggested that states of *S. lagopus*, "some of which," as Cheeseman says, "approach it very closely," have been mistaken for *S. saxifragoides*. In any case, I cannot say that I have found any examples of undoubted *S. saxifragoides*, having no bristles at all, on Banks Peninsula proper.

On the other hand, no plants of typical *S. lagopus* were found by me anywhere along the Port Hills, though, as shown above, plants were frequently found in that locality which showed more of the special characters of *S. lagopus* than have hitherto, apparently, been observed or recorded.

Except for a doubtful record in the Kaikoura neighbourhood, *Senecio saxifragoides* seems to be confined to this locality. Forms observed by me in April, 1917, on Mount Fyffe and some other points on the Seaward Kaikouras were all typical *S. lagopus*.

The specimens collected from Banks Peninsula and the Port Hills were preserved and fixed in such a manner as to make confusion impossible, and were then submitted while still fresh to Dr. Cockayne, together with certain inferences and conclusions to be drawn from them.

While both plants show a preference for high rocky situations and dark, cold faces, neither is by any means restricted to such localities. Both are

found growing among tussock and occasionally on northerly faces, and both descend nearly to sea-level in situations backed by high hills, but apparently not otherwise. It may be conjectured that both were far more widely distributed (within the limits here described) before the advent of white men, for where the ground has been permanently fenced and protected from stock *S. lagopus*, in particular, grows freely at a distance from rocks, especially on steep slopes and those facing south and south-west (as on the old Summit Track, where it rises to the ascent of Mount Sinclair on the south side, and where it runs along the southerly flank of Mount Herbert). Both also are found to grow among grass, &c., at the foot of cliffs and crags; but here, being accessible to stock, they live but precariously, and cannot form the large masses in which they cluster upon the rocks themselves. Thus both species, while now almost purely rupestral in their habit, were probably present in quantities over a very large area where they can now obtain no foothold.

4. CONCLUSIONS.*

1. Cockayne's surmise in regard to the restriction of the habitat of *S. saxifragoides* is proved to be absolutely correct, though it is possible that the plants of the Mount Herbert district are intermediate or even hybrid forms.

2. The "bristles" of Hooker's, Raoul's, and subsequent descriptions are simply glandular hairs, and both species bear them, though in varying quantity and differently distributed upon the leaf in the two cases.

3. Both species, in common with *S. bellidioides* and *S. Haastii*, have typical hydathodes at the ends of the veins, and both bear purple glandular hairs which are not mentioned in previous descriptions.

4. Neither species has the glandular hair or "bristle" as a distinctive character. The two species differ from one another only in respect of the frequency and locality of occurrence of both glandular hairs ("bristles") and silky hairs. Those differences in degree, being certainly hereditary, constitute true unit characters. The two kinds of hairs are thus unit characters common to the two species, but the abundance or sparseness of such hairs is a unit character peculiar to either species, as the case may be, and their sole distinction.

5. As the two groups of individuals keep their individuality, each in its isolated, fairly wide area, they are almost certainly microspecies, and they should be grouped together as an aggregate, with *saxifragoides* as the name of one group and some other name for the *lagopus* group. It would seem advisable that *S. bellidioides*, *S. Haastii*, and *S. southlandicus* should also be brought into this aggregate, since they have in common with them the woolly rootstock, marginal hydathodes, and glandular hairs upon the surface and the margin of the leaf.

6. Such varieties as the two under consideration, which have every distinguishing character in common, and which differ only in the hereditary degree of intensity, or the distribution of such characters, form a class of varieties (microspecies) different from those which are usually considered such through their possession of one or more quite distinct characters.

7. The question whether the remarkable variation of *S. saxifragoides* can be explained at all is only approached here with extreme caution and

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* Regarding these conclusions I have consulted Dr. Cockayne, and they owe their present form to his suggestions.

diffidence. As it is well established that the occurrence of silky hairs in great quantity is a xerophytic phenomenon,* it might be suggested that this character in *S. saxifragoides* is of climatic origin. The Port Hills, upon which *S. saxifragoides* flourishes, are nowhere higher than 1,800 ft., and most of the seven or eight high points upon them are between 1,500 ft. and 1,800 ft. in height; while the Akaroa peaks are on the average about 800 ft. higher than this, and Mount Herbert just exceeds 3,000 ft. As a consequence, the rainfall on Banks Peninsula proper is, and presumably has been for ages, considerably greater than on the Port Hills, the annual rainfall at the Convalescent Home station on the Port Hills being 25·52 in., while that of Akaroa is 44·72 in. There is no geological evidence to show that, since the formation of Lyttelton and Akaroa volcanic areas, Banks Peninsula proper and the Port Hills have not always stood in the same relation to one another as at present in respect of altitude, rainfall, and climate generally, though when the level of the whole was higher than at present, as it once undoubtedly was, the rainfall upon the Port Hills might have been more greatly reduced, relatively, than that upon Banks Peninsula proper. It might thus be argued that the drier climate of the Port Hills has directly determined the development of *S. saxifragoides* as above outlined. If this were the case we should expect to find similar forms developed in other dry localities, but it is doubtful whether any equally suitable situation exists within the limits of distribution of *S. lagopus*. If the Port Hills form a unique locality in this respect one could understand how *S. saxifragoides* has such a narrowly restricted range.

Upon this theory *S. saxifragoides* and *S. lagopus* would be classed as two varieties of the same plant, differing only in the degree of efficiency reached, under stress, in the development of their xerophytic apparatus.

Presumably, also, the other peculiarities of these two plants, such as the woolliness of the rootstock and petiole, might be assigned to the same general cause. Presumably all the six structures above described upon the leaf of *S. lagopus*, except, perhaps, the marginal glandular structures, would perform a similar function, though attention has here been confined to those two which characterize the upper surface of the blade of the leaf.

I desire to express my acknowledgements, first, to Dr. L. Cockayne, F.R.S., to whom I owe the original suggestion of this paper, and without whose kindly encouragement and invaluable aid the work could not possibly have been carried out by me; also to Miss E. M. Herriott, M.A., assistant in the Biological Laboratory, Canterbury University College, who made the microscopical examinations of the various structures and described them (as above) in the most able manner; and, finally, to Mr. R. Speight, M.Sc., F.G.S., Curator of the Canterbury Museum and Lecturer in Geology at Canterbury University College, who supplied the geological history of Banks Peninsula here given, and also very kindly photographed for me the plants of *Senecio lagopus* on Mount Sinclair (Plate XIII).

* E. Warming, *Oecology of Plants*, pp. 114, 193, 1909.

ART. XXII.—*Descriptions of New Native Flowering-plants.*

By D. PETRIE, M.A., Ph.D.

[*Read before the Auckland Institute, 11th December, 1917; received by Editors, 24th December, 1917; issued separately, 10th June, 1918.*]

1. Myosotis cinerascens sp. nov.

M. perennis, foliis culmisque pilis albis subrigidis appressis cinerascentibus. Culmi a radice complures graciles simplices vel parce divisi, 10–20 cm. alti, paene ad racemorum basim foliosi. Folia radicalia anguste obovato-spathulata ± 4 cm. longa circa 8 mm. lata obtusa, petiolis laminas aequantibus; caulina approximata consimilia ± 1·5 cm. longa lineari-obovata sessilia acuta. Racemi plerumque ± divisi breves subcapitati, raro simplices ac elongati. Flores albi breviter pedicellati; calyx ± 4·5 mm. longus, pilis rigidis patentibus subuncinatis dense hispidus, lobis brevibus acutis; corolla calyce subduplo longior anguste infundibuliformis, tubo lobis rotundatis brevibus ter quaterve longiore; stamina lineari-oblonga filamentis gracillimis duplo longiora, ad squamarum apices pertinentia; stylus maturus calycem ter quaterve superans. Nuculi oblongi, ter longiores quam lati, tenues brunnei.

Perennial, ashy-grey in all its parts. Culms from the root few or several, erect or ascending at the base, simple or sparingly branched, 10–20 cm. (4–8 in.) high, slender, leafy to near the base of the inflorescence. Radical leaves narrow obovate-spathulate, ± 4 cm. (1⅝ in.) long, 8 mm. (⅓ in.) broad, gradually narrowed into petioles about as long as the blades, obtuse rather membranous, densely hispid on both surfaces with rather long stiff appressed whitish hairs; midrib little conspicuous; cauline all much alike, closely placed and usually overlapping, linear-obovate acute sessile, about 1·5 cm. (⅝ in.) long. Racemes usually closely branched, short subcapitate, more rarely simple and more or less elongated. Flowers white on strongly hispid pedicels; calyx ± 4·5 mm. (⅙ in.) long, equalling or exceeding the pedicels, densely hispid with stiff spreading more or less hooked hairs, cut for about one-third its length into narrow acute lobes; corolla narrow funnel-shaped, nearly twice as long as the calyx, cut into broadly rounded lobes one-fourth as long as the tube; stamens linear-oblong, twice as long as the very slender filaments, reaching quite to the top of the scales; style slender, longer than the corolla, and ultimately about thrice as long as the calyx. Nutlets oblong, thrice as long as broad, thin, dark brown, shining.

Hab.—Limestone shingle-slip, Trelissick Basin, North Canterbury; 730 m. alt.: L. Cockayne! Broken River, on limestone debris, Canterbury Alps; 2,400 ft.: D. P.

This species is allied to *Myosotis Traversii* Hook. f. as Cheeseman understands that species, but by no means closely. It was almost certainly included in *M. Traversii* by Hooker f., and is no doubt the plant from the "Waimakeriri Valley" mentioned on page 195 of the *Handbook of the New Zealand Flora.* The specimens examined do not show the radical leaves in good condition, while the corollas are more or less withered and shrivelled.

2. **Myosotis saxatilis** sp. nov.

Perennis, pilis subtilibus brevibus albidis appressis viridi-incana. Caules pauci graciles, 8–12 cm. alti, supra pro parte tertia nudi. Folia radicalia obovato-lanceolata, 3 cm. longa 8 mm. lata, obtusa v. subacuta in petiolum sublatum angustata; caulina pauca subdistantia sessilia lineari-lanceolata acuta, radicalibus ½ breviora. Racemi conferte ramosi, ramis brevibus; flores 9 mm. longi, albi. Calyx alte 5-partitus, lobis linearibus; corolla infundibuliformis, tubo sublato calycem duplo superante; stamina corollae tubo vix breviora ad faucis squamas pertinentia; filamenta antheris breviora.

Perennial, greenish-grey, everywhere hoary with delicate short appressed whitish hairs. Stems few from the root, slender, more or less ascending at the base then erect, the upper third naked, 8–12 cm. (3½–5 in.) high. Radical leaves rather numerous forming a compact rosette, obovate-lanceolate, 3 cm. (1⅕ in.) long, 8 mm. (5/16 in.) broad near the tips, rather membranous, obtuse or subacute slightly apiculate, gradually narrowed into rather broad petioles about as long as the blades; midrib evident, otherwise nerveless: cauline leaves few, rather distant, sessile or the lowermost shortly petiolate, linear-lanceolate, acute or subacute, about half as long as the radical. Racemes compactly branched, branches short; flowers crowded, fairly numerous, almost sessile, 9 mm. (⅜ in.) long, white. Calyx deeply 5-partite, lobes linear acute, sparsely clothed with more or less spreading hairs; corolla funnel-shaped, the tube rather wide and twice as long as the calyx, lobes spreading shortly oblong obtuse; stamens slightly shorter than the corolla-tube, reaching just to the level of the prominent throat-scales; anthers short, broadly linear, filaments about half as long as the anthers; style as long as the corolla and elongating after flowering. Mature nutlets not seen.

On dry rocks, Shingly Range, Awatere Basin, Marlborough; about 4,000 ft.

For the opportunity of examining this plant I am indebted to Dr. L. Cockayne, F.R.S., F.L.S., of Wellington. Perhaps its closest ally is my *M. oreophila.*

3. **Myosotis diversifolia** sp. nov.

Species *M. petiolatae* Hook. f. affinis; differt caulibus erectis, foliis valde membranaceis, caulinis acutis, pilis foliorum culmorumque longioribus tenuioribus vix rigidis minus arcte appressis, pedicellis brevioribus, corollae tubo duplo longiore, antheris angustioribus subapiculatis.

Perennial; stems several (usually three or four) from the top of the moderately stout root, slender leafy to near the base of the racemes, simple or forked at the point of origin of the inflorescence, rather sparingly clothed with soft spreading white hairs, 8 in. (20 cm.) high or less. Leaves very membranous, sparsely clothed on both surfaces and along the edges with soft loosely appressed rather long delicate hairs, with a conspicuous rather fine submarginal nerve running all round; radical ± 2½ in. (6·3 cm.) long, blade elliptic 1⅛ in. (2·8 cm.) long, ¾ in. (2 cm.) broad, apiculate, sharply contracted into rather narrow softly pilose petioles somewhat longer than the blades; cauline progressively smaller and narrower, distant (internodes ½–¾ in. long), the lower shortly petiolate, the upper sessile by a broad base, all acute and apiculate. Racemes ± 3 in. (7·5 cm.) long, simple or forked many-flowered Flowers ¼ in. (6–7 mm.) long, white, shortly pedicelled

(pedicels shorter than the calyx), ebracteate, crowded in the earlier flowering stage; calyx $\pm \frac{1}{6}$ in. (4 mm.) long, cut half-way down into narrow ovate acute strongly ciliated lobes with short spreading hooked hairs at the basal part; corolla funnel-shaped, tube about twice as long as the calyx, narrow below, cut above into rather short rounded lobes; scales of the throat short and broad; stamens inserted a little below the scales, reaching as high as the clefts of the corolla-lobes; anthers narrow, scarcely elongated, almost apiculate, about three times as long as the very slender filaments to which they are attached a little below the middle; style short, scarcely exceeding the calyx even in fruit; nutlets (scarcely mature) pale brown, suborbicular.

Hab.—Ruahine Mountain-range, above the forest-belt.

Collected by Mr. H. Hill, B.A., of Napier, to whom I am indebted for specimens.

Mr. Cheeseman (*Manual*, p. 468) referred this plant to *M. petiolata* Hook. f. The latter is a coastal form, and it is doubtful if it ever grows inland or at considerable elevations. In my view *M. petiolata* is a purely coastal form, the montane plants referred to it probably belonging elsewhere. I am not certain of the colour of the corolla when fresh.

4. **Myosotis tenericaulis** sp. nov.

M. annua (?) *M. spathulatae* Forst. f. affinis; differt caulibus primo suberectis demum $\pm$ late diffusis, 20–30 cm. longis, valde tenuibus flaccidisque; caulibus foliisque cineraceis; floribus minoribus; corollae tubo limbi divisuras bis terve superante; antheris anguste oblongis subapiculatis filamenta excedentibus, vix ad faucis squamas breves latas manifestas pertinentibus; nuculorum integumentis pallide flavidis, nucleo atriore per integumenta $\pm$ pellucida manifesto.

Annual (?); stems numerous from the root, 20–30 cm. (1 ft. or less) long, suberect below, spreading and diffuse above, sparingly and distantly branched, branches elongated (internodes long), very thin and flaccid, like the leaves ashy-grey, slightly hispidulous with short appressed whitish hairs, rarely nearly glabrous. Leaves very thin, often subapiculate, with evident midrib, sparsely sprinkled with short appressed whitish hairs, the lower surface sometimes nearly glabrous; radical 3·5 cm. ($\pm$ 1$\frac{1}{4}$ in.) long, the blades elliptic-obovate contracted into slender petioles nearly twice as long as the blades; cauline distant, smaller, narrow-obovate, sessile by a broad base, obtuse or the uppermost subacute. Flowers solitary distant, usually opposite the axils of the upper cauline leaves, on very slender pedicels about as long as the calyx; calyx narrow $\pm$ 2 mm. (about $\frac{1}{14}$ in.) long, cut nearly to the base into linear subulate segments, sparingly hispidulous with the usual appressed hairs; corolla narrow funnel-shaped, the tube about one-half longer than the calyx, lobes broadly rounded about one-third as long as the tube; throat-scales short and broad; stamens narrow-oblong subapiculate, scarcely reaching to the level of the scales; filaments very short, affixed to the anthers near the base; style slender, equalling the corolla, and scarcely elongating in fruit. Nutlets shining, pale yellow especially at the thin margins, elsewhere brownish owing to the deeper colour of the nucleus of the seed showing through the rather pellucid integuments.

Hab.—Inch-Clutha, Clutha County. The exact locality where this plant was collected can be easily found. It is about a mile from the Romahapa

station on the Catlins River railway line, where the line crosses the Puerua Stream and enters the alluvial plain of Inch-Clutha. It grew in moist spots alongside the creek.

Mr. Cheeseman (*Manual*, p. 467) doubtfully referred this plant to *M. spathulata* Forst. f., which is its nearest ally, though not a very close one. He further mentions that it has been collected by the late Mr. T. Kirk near Winton, Southland County. It appears to be confined to the southern lowlands of Otago.

5. **Myosotis macrantha** Hook. f. var. **westlandica** var. nov.

A forma typica differt foliis radicalibus longioribus multo tenuioribus anguste obovatis molliter pilosis, venis a costa ad venam submarginalem conspicuam oblique progredientibus, culmis longioribus gracilioribusque, floribus flavis.

In a moist shady ravine on Rangi Taipo, Jackson's, Taramakau River; about 4,000 ft.: L. Cockayne, D. P.

When better known this form may prove to be a distinct species; for the present it seems better to rank it as a variety.

6. **Pterostylis areolata** sp. nov.

Gracilis glabra $\pm$ 15 cm. alta. Folia pauca, caulina, sessilia, culmum amplectentia; inferiora scariosa squamiformia; superiora (plerumque 3) valde tenuia, in siccitate pellucida, lanceolata v. oblongo-lanceolata, acuta v. subacuta, plurinervia manifeste areolata, 3·5–4 cm. longa 1 cm. lata; culmo folium summum longe excedente. Flores solitarii 3·5 cm. longi $\pm$ 1·5 cm. lati. Galea pro parte majore erecta, pro parte tertia recurva; sepalum superius in apicem brevem acutum haud filiformem desinens, petalis acutis paulo longius; labii inferioris divisurae anguste obcuneatae, in apices subulato-filiformes summam galeam haud excedentes desinentes; labium subcrassum lanceolato-oblongum subacutum; columna gracilis elongata galeae partem erectam aequans.

Slender, glabrous, $\pm$ 15 cm. (6 in.) high. Leaves 4 or 5 (in the specimens seen), rather distant, sessile and sheathing the stem; the lower reduced to scarious sheathing scales; the upper very thin, pellucid when dried, 3·5–4 cm. ($\pm$ $1\frac{1}{2}$ in.) long, 1 cm. ($\pm$ $\frac{3}{8}$ in.) broad, lanceolate or oblong-lanceolate, acute or subacute, entire, narrowed towards the base, with conspicuous veins running nearly straight along their whole length and connected by delicate more or less oblique veinlets into an open network; the uppermost leaf placed about half-way up the stem and reaching about half-way up to the flower. Flowers solitary, 3·5 cm. ($\pm$ $1\frac{1}{2}$ in.) long, $\pm$ 1·5 cm. ($\frac{5}{8}$ in.) broad, green more or less streaked with reddish-brown; galea erect for two-thirds its length, then sharply bent forwards; upper sepal ending in a short more or less acute non-filiform tip, a little longer than the acute petals; lower lip narrow-cuneate for nearly half its length, forking widely into narrow obcuneate subulate-filiform-tipped lobes that do not exceed the top of the galea; lip brownish when dried, rather thick and firm, lanceolate-oblong, subacute with exserted tip; column slender, as long as the erect part of the galea, the lower lobe of its wings large long obtuse.

Hab.—Base of Shingle Peak, Awatere Valley, Marlborough; 3,000 ft.; in shade: L. Cockayne! Bealey, Waimakariri Valley, Canterbury: T. Kirk!

This appears to be a well-marked species. The late Mr. Kirk referred his specimens, which are in fruit and are rather stouter than Dr. Cockayne's, to *P. micromega* Hook. f., but they are destitute of radical leaves, while the cauline leaves are much larger and broader than those of *P. micromega*, and do not extend above the middle of the stem. As I have seen only dried specimens, the details of the structure of the column may be imperfectly sketched here.

7. Poa campbellensis sp. nov.

Species *P. pusillae* Berggren affinis: differt foliis numerosis erectis v. suberectis conduplicatis apice obtusis; ligulis longioribus ± oblongis laceris v. erosis; spiculis paulo majoribus viridibus colore purpureo-spadiceo ± tinctis; glumis florigeris subacutis basi pilis crispulis brevibus exigue instructis; paleis apice subalte bifidis ac a carinis delicate ciliatis.

Culms very slender densely tufted, leafy below and usually clothed by the sheaths of the cauline leaves to above the base of the panicle, 5–10 cm. (2–4 in.) rarely 15 cm. (6 in.) high. Basal leaves much shorter than the culms, erect or slightly spreading, narrow blunt-pointed, smooth, folded, rather stiff; sheaths about as long as the blades, broad, thin, loose, membranous, striate; ligules variable in length, shortly oblong (rarely longer and narrowed upwards), thin and scarious, erose or lacerate at the tops. Panicle small, 2·5–4 cm. (1–1½ in.) long, narrow-ovate, of 6–9 spikelets placed on rather long glabrous or slightly scabrid pedicels; branches capillary, the lower much longer. Spikelets ± 7 mm. (¼ in.) long, ovate-lanceolate, greenish, faintly stained with purplish-brown, 2–3-flowered; outer glumes slightly unequal, about two-thirds as long as the flowering-glume immediately above, smooth or slightly scabrid along the keel; the lower narrow-ovate acute faintly 3-nerved, the upper broader subacute strongly 3-nerved; flowering-glumes ovate-oblong, subacute, thin, more or less scarious around the tops, smooth except on the finely scabrid keel, with a scanty tuft of delicate crisped hairs at the callus, 5-nerved; the two lateral nerves faint, the median nerve alone reaching the top; palea a little shorter than the flowering-glume, rather deeply bifid at the top, finely ciliate along the nerves.

Hab.—Campbell Island, and Port Ross in the Auckland Islands: B. C. Aston! (January, 1909).

The Port Ross specimens are considerably taller than those from Campbell Island. In my report on the Gramina in vol. ii of *The Subantarctic Islands of New Zealand* this grass was united with my *Poa incrassata*. I am now satisfied that this treatment of the plant is incorrect. The original description (*Trans. N.Z. Inst.*, vol. 34, p. 394, 1902) and that given in Mr. Cheeseman's *Manual* (p. 911) are therefore the correct ones. Mr. Cheeseman has noted that *Poa incrassata* is most nearly allied to *Poa exigua* Hook. f. The present species has its nearest ally in *Poa pusilla* Berggren.

ART. XXIII.—*The Geomorphology of the Coastal District of South-western Wellington.*

By C. A. COTTON, Victoria University College, Wellington.

[*Read before the Wellington Philosophical Society, 12th December, 1917; received by Editors, 31st December, 1917; issued separately, 10th June, 1918.*]

Plates XIV, XV.

CONTENTS.

INTRODUCTION.

THE coastal district of south-western Wellington (fig. 1), forming part of the fertile "Manawatu" and largely comprised within the limits of Horowhenua County, presents a considerable variety of physiographic features all of comparatively modern growth* and explicable on an assumption of a geological history of a somewhat unusual kind.

I have been informed by Dr. L. Cockayne and Mr. A. H. Cockayne that the ecology and agriculture of the district are closely related to the physiography, and I am tempted to present this somewhat sketchy description and attempted explanation of the forms in the hope that it may be of use as a basis for further studies.

THE FOUNDATION OR OLD LAND.

The skeleton or foundation of the coastal district of south-western Wellington is the upland block of somewhat old rocks sculptured into strong relief that forms the Tararua Mountains and the lower ridges farther south. Lithologically these rocks are greywacke-sandstones with occasional bands of argillite, the latter much sheared by earth-movements.† All are closely

* Geologically the whole history of the lowland is comprised within a portion of the Notopleistocene period.

† The early geologists termed these rocks the "Rimutaka series," a local name that might be now appropriately used for them. Subsequently to the issue of the geological map of 1873 the name "Rimutaka" gave place to "Maitai," as it was believed that the two formations were identical; but it was used occasionally by McKay in the "seventies" for the whole or part of the rocks of the Rimutaka and neighbouring ranges.

folded, so that the strata are now everywhere nearly vertical, and the strike, though variable from point to point, averages a little to the east of north. Some bands of the rock are thoroughly shattered and allow of the percolation of water along closely spaced joints, so that they yield rather readily to deep weathering and erosion. Other bands have escaped shattering or have had the network of crevices re-sealed by a deposit of secondary mineral matter, so that there are now few joints, and weathering and erosion go on relatively slowly. These latter relatively resistant bands of

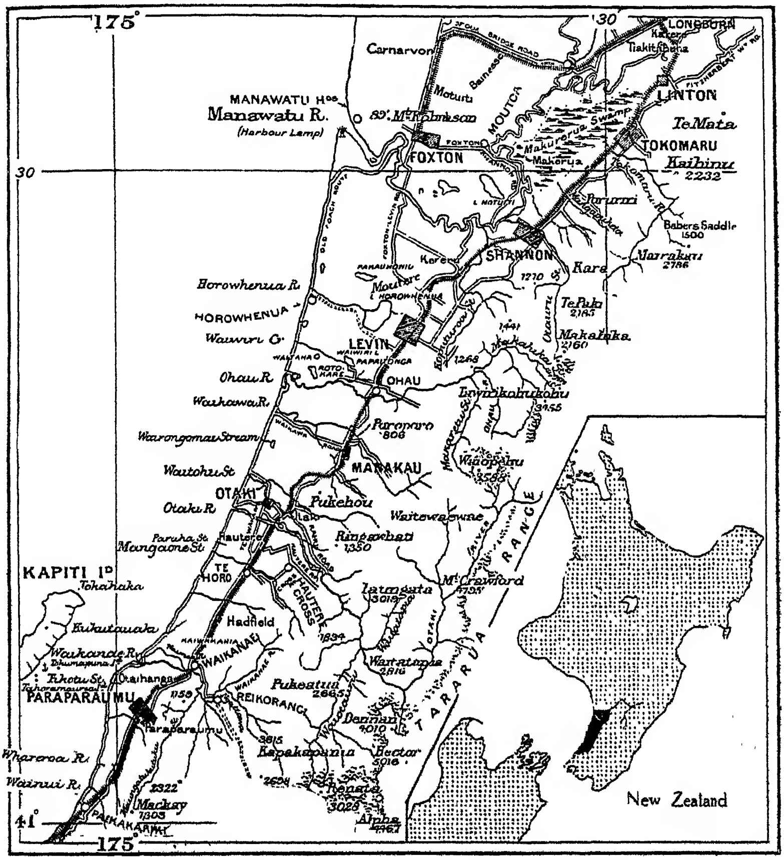


FIG. 1.—Map of the coastal district of south-western Wellington, including the upland ranges eastward to the main divide. Scale, 10 miles to 1 in. The inset map shows the locality.

rock stand out boldly as ridges, while the bands of shattered rock are now followed by streams, and, where of considerable breadth, are reduced to somewhat subdued forms with moderate relief.

It is not known with certainty that the alternating bands of resistant and weak rocks, which owe their varying strength, as just noted, to the extent to which they are fissured, correspond exactly to the bedding; but they are at least elongated in the same general north-north-easterly direction, and the shattering in the weakened bands was probably caused by

the ancient folding. (An exceptional belt of shattering close to the city of Wellington, which crosses the strike diagonally, is not here referred to. It appears to be connected with fault movements of a much later date than the folding of the rocks.*)

The texture of the dissection on both the higher ridges of resistant rock and the lower belts of subdued topography is somewhat fine, owing, no doubt, to the low permeability of the mantle of residual clay that results from the weathering of the greywacke.

The development of the present mature topography seems to have been interrupted from time to time by renewed uplift, as in the Wellington peninsula farther to the south-west,† but the high valley-floors of the earlier cycles are here maturely dissected, and the land-forms of the various cycles merge almost or quite completely into one another. Some of the later pauses in the uplift are probably recorded by the fragmentary terraces in some of the valleys. These are generally rock terraces, but some are formed of alluvium—*e.g.*, in the Otaki valley a thick mass of fluviatile gravel underlying a portion of a terrace and extending below the present level of the river suggests trenching, due to uplift, and later refilling of the trench, perhaps during a temporary submergence preceding an uplift to which the cutting of the present narrow inner valley of the river is due. The terrace features cannot be ascribed wholly to vertical movements of the land, however, for they must be closely connected with certain to-and-fro movements of the shore-line which will be described below.

The margin of the upland block is a mature coast-line rising in places as high cliffs, but fronting the sea now only at the south-western end, beyond the limits of the district here dealt with, and bordered elsewhere by a coastal lowland the width of which increases north-eastward. With respect to this lowland of later growth the upland block may be spoken of as the "old land." The ancient coast-line of the old land appears to have originated as a fault coast, for its almost straight north-east and south-west trend crosses the grain of the country obliquely. Whatever the initial form may have been, however, a mature coast of simple outline developed by marine erosion now forms a nearly straight boundary-line between the upland block or old land and the strongly contrasted coastal lowland.

The Coastal Lowland.

Different parts of the coastal lowland are of different ages, and their present topographic forms have been developed in different ways, and the materials of which they are composed, though in some cases originally identical, are in different stages of consolidation and decay, so that they yield very different soils. The materials also came originally from two distinct sources.

The divisions of the lowland are best introduced by a discussion of the conditions under which it seems to have come into existence. All the features of the lowland may have been produced by an alternation of retrogradation (or retreat of the shore-line under wave-attack) with progradation (or advance of the shore-line due to accumulation of the waste of the land). Such an alternation is necessarily connected with a fluctuation in the supply

* C. A. Cotton, Supplementary Notes on Wellington Physiography, *Trans. N.Z. Inst.*, vol. 46, pp. 294–98, 1914.

† C. A. Cotton, Notes on Wellington Physiography, *Trans. N.Z. Inst.*, vol. 44, pp. 245–65, 1912.

of waste, leading to a fluctuation in the ratio of wave-energy to load, for, when the supply of waste is small, waves attack a coast vigorously, cut it back, and draw much of the waste produced in this process back into the deeper water off shore, where it comes to rest; whereas when there is a large supply of gravel or sand, either brought in by local rivers or transported along-shore by the activity of waves and currents from a more distant source, the energy of the waves is used up in maintaining a graded off-shore profile of the bottom as the abundant waste accumulates at all depths, and some of the material is thrown up on the beach, so that the shore-line advances seawards, leaving a prograded strip of new land.

In the case in question it is probably the supply of sand, which comes from rivers farther to the north-east, that has fluctuated, rather than that of gravel brought down by local streams. The cause of the fluctuation is not apparent. Changes of level of small amount would have an effect, no doubt, by disturbing the graded profile of the neighbouring sand-covered sea-bottom, and would perhaps produce alternate overloading and underloading of the waves at the shore-line. The fluctuation in the supply of sand is too great, however, to be attributed to that cause alone. I have not recognized the concomitant effects of such small movements on the coastal topography, nor succeeded in distinguishing them from the effects of advance and retreat of the shore-line, and so they are necessarily ignored in this account.*

Theoretical Discussion of the Growth of a Coastal Lowland under Conditions of Fluctuating Waste-supply.

Where a coast, perhaps originally a fault coast—though this is not essential—has been cut back to the mature stage, like the ancient coast of the old land of south-western Wellington (fig. 2, A), and a change to progradation takes place, a strand-plain, generally dune-covered, is developed (fig. 2, B). The material is mainly "imported" sand, if it is assumed that the excess of material has been brought from another section of the coast, but there will be mixed with it some gravel of local origin near the mouths of streams. As the streams grow in length seaward, however, with the growth of the prograded strip, they are constrained to aggrade so as to build up channels with sufficient slope to maintain their flow, and a proportion, perhaps the whole, of their gravel is thus used up, and accumulates as fans along the base of the cliffs of the old land (fig. 2, B). Clearly, if these streams are somewhat closely spaced and bring down much gravel their fans will become confluent, forming a piedmont alluvial plain; but, on the other hand, if their supply of gravel is smaller in proportion to the amount of sand being thrown up along the shore-line they will remain separate, and on the spaces between them dune sand may accumulate to a considerable thickness.

There is thus developed a coastal lowland of general seaward slope, with a somewhat irregular surface, and possibly with a width of many miles.

* Adkin reports that a trial well-boring on the lowland passed through a swampy layer (*i.e.*, a land surface) far below present sea-level (*Trans. N.Z. Inst.*, vol. 43, p. 498, 1911). I have not been able to obtain official records of any of the bores that have been put down; but if this interpretation is correct it indicates that the lowland, during an early period of outward growth, advanced, or was at least maintained, in spite of considerable subsidence (as in the case of the Canterbury Plain). To make this possible the supply of waste at that stage must have been very abundant.

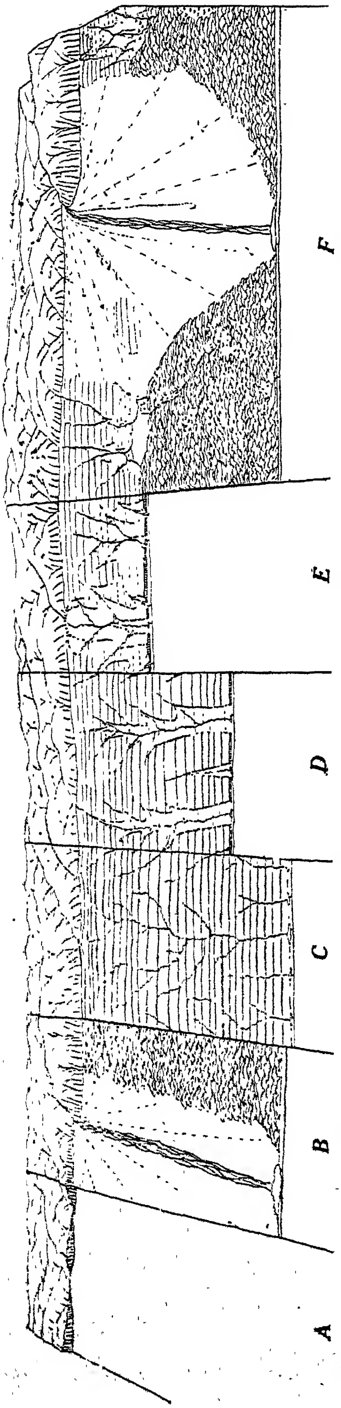


FIG. 2.—Diagram of successive stages in the growth of a composite coastal lowland during two periods of progradation separated by one of retrogradation.

If now the landward dunes have become fixed by vegetation and somewhat consolidated, they will in time have a normal drainage system developed on them, and their irregularity of surface will be reduced by the filling of the hollows and the wearing-down of the initial hills, so that their surface will become a peneplain (fig. 2, C).

If now after a period of slow progradation, perhaps followed by a period of stationary shore-line, retrogradation begins again, the seaward-sloping coastal lowland, as its toe is cut back to a line of cliffs of growing height, will be dissected owing to the shortening of its streams. Since the dune-sand areas lie between the larger streams from the old land, they will be traversed only by systems of small streams arising on them or heading on the cliffs behind. The energy of such streams is slight, but they work on very weak material and so erode quite rapidly (fig. 2, D). The larger streams from the old land will now trench the fans they formerly built, and they may destroy the fan-surface altogether or reduce it to fragmentary terraces, developing stream-eroded plains at lower levels, which may in places be widened so as to plane down parts of the dune-sand areas.

The lowland will now resemble in a general way a dissected coastal plain of subaqueous origin, but there will be differences in detail, for the initial form in this case is a subaerially graded surface, and when the streams entrenched below it have again become mature the slopes of their valley-plains will approximate to that of the interfluves, and also such of the interfluvial areas as are underlain by dune sandstone will not be quite flat, but will retain the small relief of a peneplain.

There may be pauses in the retrogradation of the coast, and even reversals from time to time, and thus several series of terraces or valley-in-valley forms may be developed (fig. 2, E).

It may be postulated that after the coastal lowland has been cut back by

the sea to perhaps half, or less than half, its former width progradation again sets in, and a new strand-plain, dune-covered like its predecessor, grows seaward from the recently cut cliffs. This will give rise to various modifications in the form of the dissected lowland. It will cause vigorous aggradation in all the gravel-bearing streams from the old land, and some of these may completely fill the valleys they have previously excavated in the lowland. Thus the fans are reconstructed (fig. 2, F). Intercalated short periods of retrogradation or other causes may lead to channelling of the fans from time to time, followed by renewed aggradation, and similar results may be produced by fluctuation of level. Thus there may be a considerable amount of complexity in the structure of fans.

Along the border of the inter-fan areas the even seaward slope of the lowland is not so readily restored. Some aggradation will take place, however, along the lines of the small dissecting streams, but irregularly, the greatest effects being seen where the channels, perhaps kept open for a time across the newer strand-plain, becomes blocked by sand-dunes, forming lakes partly within and partly beyond the border of the older dissected lowland (fig. 2, F). These, when filled, become swamps with arms extending up the floors of the tributary valleys, which are in process of aggradation with fine silt. Similar swampy flats will occur as normal features also among the dunes on the newer strand-plain.

Meanwhile the cliffs along the toe of the older lowland will be reduced to gentler slopes by subaerial erosion, which goes on quickly in this soft material, and reduction of the surface will still continue. Parts of it are by now maturely dissected, and there may be close interfingering between the spurs of the older and the dunes of the newer lowland.

In a coastal lowland developed as outlined above four quite distinct physiographic types of surface can be recognized: (1) The older dune-sandstone areas of the dissected older lowland, with peneplained tops, mature topography towards the margins, and more or less dissected terraces in the valleys; (2) the gravel fans, which may still be confined between low banks of the dune sandstone or may overlap its peneplained surface; (3) the newer sand-dunes, which still exhibit the forms due to accumulation; and (4) swampy flats, which have accumulated in lakes due to ponding among the newer dunes or between these and the toe of the older lowland, or are the result of aggradation in the silt-bearing small streams trenching the older lowland. In the coastal lowland of south-western Wellington all four of these physiographic elements are important

An Alternative Explanation.

An alternative explanation which would account for the existing forms in the broader part of the lowland fairly well would make the "older lowland" of the foregoing a coastal plain of subaqueous sands, which was subjected to subaerial erosion with the shore-line stationary for a period long enough to allow of peneplanation, and afterwards cliffed at the margin and dissected. The remaining events would be the same as those outlined in the previous explanation. An objection to this explanation is found in the nature of the material of the older dissected lowland, which will be referred to on a later page; and an argument in favour of the explanation previously given is found in the clearly decipherable history of the lowland at its extreme south-western end (at Paekakariki), where there is evidence of alternating progradation and retrogradation on a scale sufficiently large to warrant the assumptions made.

The Paekakariki Coast.

South-westward from the tapering end of the lowland at Paekakariki the cliffed margin of the old land is now being cut back, and there is no evidence to show whether this part of the coast has ever been prograded. The dune-covered strand-plain is now extending in that direction along the base of a line of high, fresh cliffs cut diagonally across one of the resistant ridges of the old rocks (Plate XIV).

A mile or two north-eastward, however, there is evidence of the former presence of a strand-plain and of its removal prior to the growth of the present lowland. This evidence is found in the presence of cliffed remnants of fans of locally-derived gravel, one of which is of such dimensions that the fan when complete must have extended seaward about a mile beyond the margin of the old land.

These fans were built forward in what may be termed the first (strictly the *n*th) progradational phase (fig. 3, B), following the first (strictly *n*th) retrogradational phase, in which the cliffs of the ancient coast-line of the

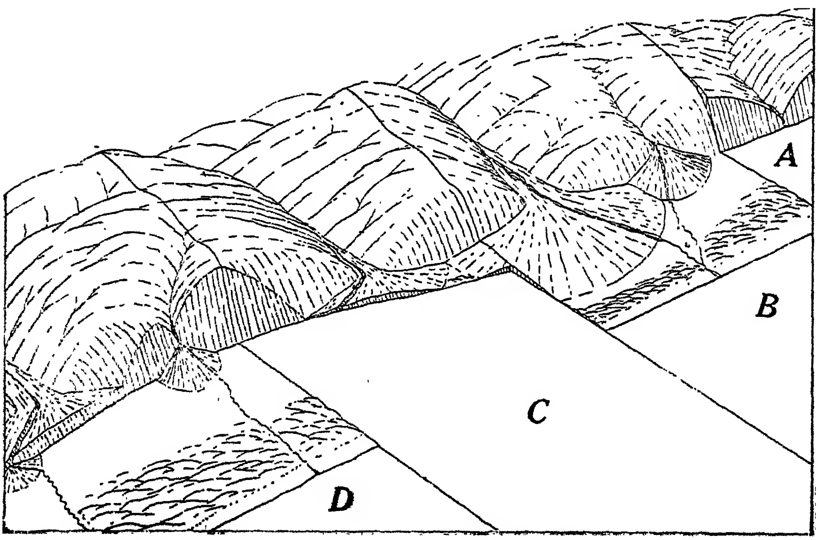
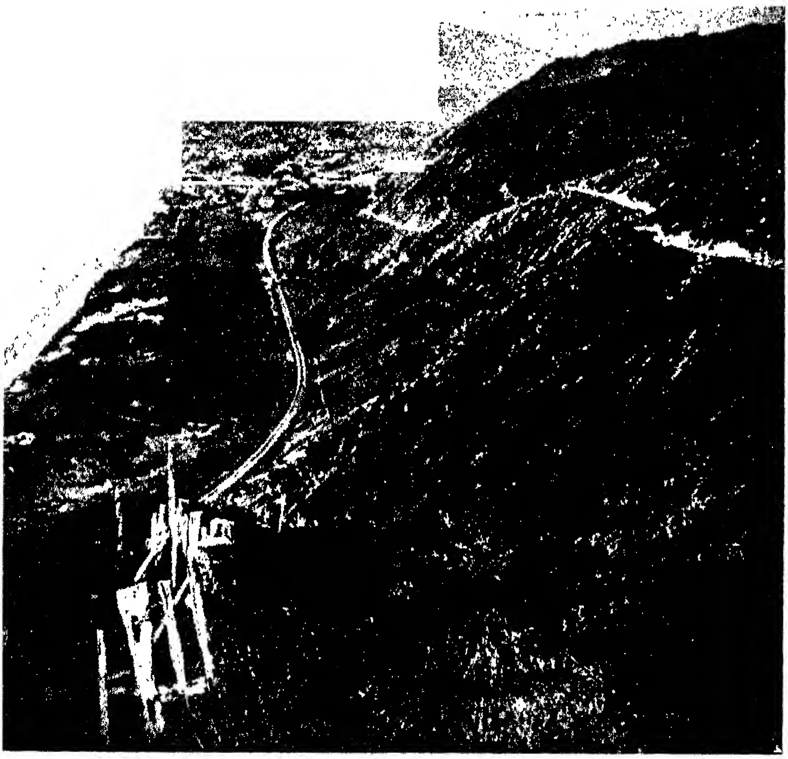


Fig. 3.—Diagram of successive stages of a coast alternately retrograded and prograded.

old land were cut (fig. 3, A). These cliffs are now subdued and rounded, and pass by smooth concave curves at the base into the fans and talus slopes.

The fans are irregularly truncated by a younger line of cliffs developed in a second [($n+1$)th] retrogradational phase, and these are cut back far enough in places to intersect the line of older cliffs (fig. 3, C). The cliffs previously referred to as lying behind the extreme end of the lowland are continuous with these of the second [($n+1$)th] retrogradational phase.

In front of this newer line of cliffs lies the modern lowland or dune-covered strand-plain, a belt of dunes enclosing between themselves and the cliffs a narrow strip of marshy plain (fig. 3, D). Fig. 4 is a panoramic sketch of this portion of the coast, illustrating the features described. Plate XV, fig. 1, is a photographic view showing the truncated fans.



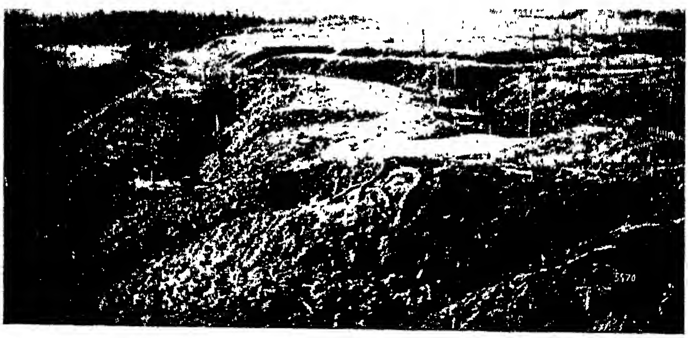
[C. A. Cotton, photo.

General view of the narrow southern end of the coastal lowland, looking northward from the cliffs south of Paekakariki.

Face p. 218.]

[C A. Cotton, photo.

Fig. 1.—Fan with cliffed seaward margin, north of Paekakariki.



[G. L. Adkin, photo.

Fig. 2.—Dissected bench of Otaki sandstone near Shannon.

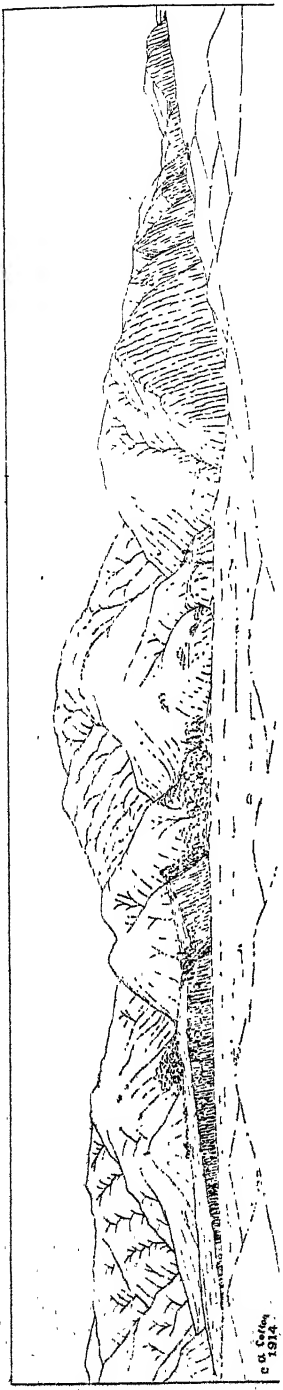


FIG. 4.—The Paekakariki coast, viewed from the modern fixed dunes. Angle of view, south-east to south-west.

Another Alternative Explanation.

An account of the geological history of the coastal lowland which diverges considerably from that assumed in the explanation of the physiography here adopted was given by Adkin,* whose account deals in particular with that part of the lowland adjoining the Ohau River.

Adkin's classification of various stages in his concept of the history of the lowland as Early Pleistocene, Middle Pleistocene, Later Pleistocene (First, Second, and Third stages), and Recent must be discarded, as he had no means of correlation with deposits of Pleistocene age elsewhere; and for the present purpose the stages "Early Pleistocene" to "Recent" may be renamed stages 1 to 6.

According to his interpretation, at stage 1 the Ohau River built a great fan over hypothetical undissected uplifted Pliocene formations with a plane surface, the latter being vaguely "inferred from the configuration and character of the superimposed fluviatile deposit." Large parts of the surface of the fan formed at this time are regarded as surviving to the present day, though buried by a marine deposit and re-exposed by erosion in the intermediate historical stages.

Stage 2 was a period of complete submergence of the lowland beneath the sea. This was followed by a period of still-stand, succeeded by uplift continuing to the present day. During the submergence at stage 2 a "raised-beach formation" was deposited, consisting of beach sands spread over the whole area of the lowland partly during the advance of the sea and partly during its retreat. This "raised-beach formation" comprises the partially consolidated sands of the older lowland. Adkin states that its present level surface is not the original one, as it has been lowered by erosion. It is not clear, however, to what base-level he ascribes the planation, or at what stage of the history it occurred. Dissection of the surface by small streams is mentioned in the description of an illustration.

* G. L. ADKIN, The Post-tertiary Geological History of the Ohau River and of the Adjacent Coastal Plain, Horowhenua County, North Island, *Trans. N.Z. Inst.*, vol. 43, pp. 496–520, 1911.

The remaining stages are marked by changes in the courses of the Ohau and other streams over the Ohau fan, for the explanation of which Ferrel's law is invoked, though it is much more probable that such changes as have taken place in stream-courses have resulted from spilling over as a normal accompaniment of aggradation. At the same time the shore-line advanced steadily seaward. It is not clear whether this is regarded as entirely the result of an inferred movement of uplift, but this is probably what the author had in mind, as he speaks of the whole lowland as a coastal plain. The new land formed thus was progressively covered with sand-dunes, which impounded lakes.

The account is somewhat difficult to follow, but the foregoing is a fair summary. Adkin regards the gravel plains, such as the Ohau fan, as the oldest, instead of placing them among the youngest elements of the lowland physiography, as is done in the explanation now offered; and his conclusion that any portions of the existing fan-surfaces or gravel plains were in existence prior to the deposition of the sands of the older lowland is an extremely doubtful one, whatever the correct explanation of the mode of accumulation of those sands may be.

It must be added that Adkin's work is obviously based on a large amount of careful field-work; and his mapping in the Ohau River district (Horowhenua) is extremely useful.

Subdivisions of the Lowland.

The Otaki Series.

The oldest physiographic element in the lowland is, then, the dissected peneplain of soft sandstone corresponding to the "older dune-sand areas" of the theoretical discussion previously given, and comprising the "raised-beach formation" of Adkin. To the lithological formation of sandstone thus indicated the name *Otaki series* may be applied as a local formation-name, as it is well developed just north of the Otaki River and town.

Topography on the Otaki Series.—The topography is that described in the theoretical section as developed on the "older dune-sand areas," and shown diagrammatically in fig. 2, F (see also Plate XV, fig. 2). I agree with Adkin* that the gently undulating tops of the broad benches of this formation are parts of a surface of erosion and not of deposition. In some parts of the district a considerable area of the surface of the Otaki series consists of broad terrace-remnants of valley-floors at intermediate levels developed generally by very small streams which now make their way along the flat, swampy floors of inner valleys. A striking characteristic of the small dissecting streams arising within this formation is the steepness of their valley-sides, which remains practically constant as the width of the floor increases, and the same slope continues around the valley-heads. To their very heads the valleys are box-shaped rather than V-shaped. The slopes separating the broad terraces at intermediate levels were evidently once exactly similar to those of the inner trenches, though they have become somewhat dissected and broken down since the streams were revived and undercutting of these slopes ceased. Where the terraces have been developed by gravel-bearing streams heading in the old land they are gravel-covered.

Distribution of the Otaki Series.—Between the southern end of the coastal lowland and the Manawatu River the Otaki series, with its charac-

* *Loc. cit.*, p. 509.

teristic topography, covers an area of perhaps sixty square miles, of which about half consists of nearly flat summits. One considerable area occurs between the Otaki and Ohau Rivers; an "island" of it, surrounded by gravel plains evidently parts of the Ohau fan spread by distributaries of that river, occurs at Weraroa, where the Central Development Farm of the Department of Agriculture is situated partly on this formation and partly on the fan; and there is then a nearly continuous bench, broken only by some gravel-covered valley-floors, extending north-eastward for twenty miles.

Lithology and Structure of the Otaki Series.—The prevailing material in the Otaki series is grey sand similar in mineral composition to that of the present beach and the associated dunes. In addition to quartz, the sand contains a considerable proportion of feldspathic, ferromagnesian, and iron-oxide grains. The mineral grains, including those of quartz, though not completely rounded, have their angles smoothed off, and they thus contrast very strongly with the sharp, angular grains of the present beach. This suggests aeolian accumulation. All the samples examined are somewhat weathered, however, and the rounding of grains may be ascribed in part to weathering.

The more or less coherent sandstone formed of this material weathers at the surface to a residual sandy clay, usually containing scattered spheroidal masses of the sandstone. The permeability seems not to be great, for the water-table is generally close to the surface. Much water seeps out along the bases of even low scarps, and necessitates draining.

In the few sections where bedding has been noted the beds are inclined at about 35°. It is quite clearly cross-bedding on a large scale, and again suggests subaerial accumulation. Cross-bedding and also ripple-mark are noted by Adkin.* A horizontal pseudo-stratification, due, apparently, to deposition of iron, is also generally present. Though less prominent, it seems to resemble that noted by Berkey† in the aeolian San Juan formation of Porto Rico.

The non-discovery of fossils,‡ though a negative character, points also to the possibility of subaerial accumulation of the sand of the Otaki series.

Clay lenses and bleached soil-beds, which are interbedded with the sandstone, accumulated, no doubt, in lakes and swampy areas impounded among dunes. The clay-bed between upper and lower sands noted by Adkin,§ which he ascribes to marine deposition at a period of maximum depression, is perhaps one of these.

In one section near Shannon layers of small pebbles occur interbedded with the sand. Here is probably the course of one of the smaller streams from the old land, or perhaps the margin of one of the larger fans. If gravel fans and dune sands accumulated side by side, as is assumed in the theoretical section, there must be a considerable amount of intermixture of material along the transition lines where gravel passes laterally into sand. Along these lines, indeed, a complex interfingering of gravel and sand beds may be expected.

The Fans or Gravel Plains.

Throughout the length of the lowland there are numerous gravel fans, both great and small. The largest are those of the Otaki and Ohau Rivers,

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* *Loc. cit.*, p. 507.

† C. P. BERKEY, Geological Reconnoissance of Porto Rico, *Ann. N.Y. Acad. Sci.*, vol. 26, pp. 1–70 (see p. 50), 1915.

‡ G. L. ADKIN, *loc. cit.*, pp. 497, 507.

§ *Loc. cit.*, p. 507.

which have a combined area of about forty square miles. Some parts of their surfaces are thickly covered with small boulders or coarse gravel; others have a gravelly soil; while others, again, have a superficial layer of silt overlying gravel. Most of the fans are trenched and terraced to a small extent. The surfaces of the fans and of terraces cut in them are very similar to one another, as are also gravel-covered terraces within the border of the old land. All these may be classed as gravel plains. The gravel-bearing streams are at present aggrading as though to refill the trenches in the fans. The actual stream-beds are, therefore, areas of bare gravel over which the streams flow in changing, braided channels. As previously mentioned, the upper surface of the Otaki formation passes in some places into that of a fan without any abrupt break of slope.

The Delta of the Manawatu.

More or less analogous with the fans of the southern part of the lowland is the delta of the Manawatu River; but this is one, perhaps the chief, of the sand-supplying rivers. Its delta is composed mainly of fine material, and its gradient is very gentle as compared with that of the gravel fans. The Manawatu delta forms a plain of wide extent lying at present almost entirely on the north side of the river, and continued up-stream by a wide flood-plain, below which the river is now slightly entrenched, and above which there are broad terraces on the northern side. The seaward margin of the delta is covered with dunes, some belts of which extend inland many miles. The Manawatu River at present bends to the south-west after emerging from its gorge across the old land, and at a not very distant date it swung still farther to the south. The toe of the bench formed by the Otaki series is here cut back to a line of cliffs by the action of the river, and at the base of these a considerable area of ill-drained flood-plain, now abandoned by the river owing to its slight entrenchment, forms the great Makurerua Swamp (see fig. 1). The whole of the delta plain was formerly swampy, but a great part has been artificially drained.

The Modern Dunes.

The modern dunes are built of grey sand similar to that forming the sandstone of the Otaki series. All except a narrow belt close to the sea are fixed by vegetation, but beneath the superficial layer of humus the sand is still quite loose. The belt of dunes has a width of from three to six miles, and their average height is 170 ft. Adkin notes that their general arrangement is in ridges at right angles to the coast-line.* The shore-line of the dune-covered foreland advances as a broad cusp towards Kapiti Island (a high island of old rocks some four miles from the mainland). This is evidently an early stage of island-tying.

Lakes and Swamps.

Several lakes and many small ponds and swamps formed by the silting-up of ponds lie between the modern dunes and the margin of the other physiographic elements of the lowland, and there are many swampy areas among the modern dunes. The valley-floors in the Otaki formation are practically all swampy, as a result either of normal aggradation with fine silt or of ponding by sand-dunes followed by accumulation of silt. The largest swamp in the district—the Makurerua Swamp—has been referred to above.

* G. L. Adkin, *loc. cit.*, pp. 514–15.

ART. XXIV.—*New Zealand Ironsands: an Historical Account of an Attempt to Smelt Ironsands at Onehunga in 1883.*

By J. M. CHAMBERS.

Communicated by Mr. Evan Parry.

[*Read before the Technological Section of the Wellington Philosophical Society, 13th June, 1917; received by Editors, 31st December, 1917; issued separately, 17th June, 1918.*]

IT is extremely difficult after a lapse of nearly thirty-five years to obtain a complete history of this undertaking, as the directors of the New Zealand Iron and Steel Company (Limited) are all dead—in fact, almost everybody who had any connection with it. Its records have been lost or destroyed, and the only data I have have been obtained from a private letter-book and a few odd documents which I found amongst my father's papers.

In 1866 Mr. John Chambers arrived in New Zealand, and soon afterwards saw the ironsand on the beaches of Taranaki. He was much impressed with it as a valuable asset, if the material could be converted into marketable iron. From some early settlers he learnt that 100 tons of sand had been sent to Staffordshire, where it was manufactured into iron by David Hipkins, who wrote that he smelted and puddled the sand into bars, sheets, hoops, boiler-plates, and fencing-rods, afterwards making it into horse-shoes, chain, &c. All were tested and pronounced equal to any of the Staffordshire irons; but owing to cost of manipulation he would not recommend his principals to obtain further supplies or establish a works in New Zealand.

Later, in 1876, Mr. Chambers took a parcel of ironsand to England and the United States. He interviewed many ironmasters, but could get none sufficiently interested to experiment seriously with the samples, excepting in laboratories, where a few pounds of iron and steel were produced in crucibles.

In 1886 I attended the Indian and Colonial Exhibition, where there were exhibited a parcel of sand and some iron manufactured by the above company. While in London I was introduced to W. T. Jeans, Price Williams, and Sir Henry Bessemer, all of whom were interested in the sands of New Zealand and Canada. Arrangements were made with Sir Henry Bessemer to carry out a series of experiments. His report was unsatisfactory, for, although he claimed that the best-quality iron and steel could be produced, it would require a great deal of research work, and he was too old to go on with it.

Just before Sir William Siemens died, in 1883, he stated that his attention had been called to the ironsand in New Zealand and Canada, containing about 50 per cent. of metallic iron, and he demonstrated with a patent rotating furnace that he could manufacture iron from the ironsand of Canada, producing iron balls in four hours, which were then treated in the open-hearth furnace and converted into mild steel. At that time his process was tried in Pittsburgh, but unfortunately it did not prove a commercial success, on account of cost.

Mr. John Chambers visited the Philadelphia Exhibition in 1876, and there tried to induce men in the iron and steel trade to test the ironsand; but nothing could be arranged, as all the ironmasters of America were fully occupied in building additional works to handle the trade which they could

easily get in America for all the iron that could be produced from ordinary iron-ore at a cheap rate. But before leaving New York Mr. Chambers heard that Mr. Joel Wilson, of Dover, New Jersey, had in 1873 patented a furnace which he claimed would treat ironsand and convert it directly into wrought iron; but everything was in an embryo state, and it was arranged for an agent to watch the work of Mr. Wilson, who claimed in 1882 to be able to manufacture successfully from sand. Mr. Guy H. Gardner, of New York, obtained an option on the New Zealand patents, purchasing them jointly with Mr. Chambers; and so sanguine was the inventor that he agreed to send out his best man, Mr. W. H. Jones, to demonstrate the working of his patent in New Zealand.

A full-size furnace was erected in 1882 to manufacture 3 tons of iron per day. The furnace was built from a drawing accompanying patent specifications granted to R. L. Malcolm (J. Wilson)* and G. H. Gardner,† except that the reducing-furnace contained eight retorts, instead of sixteen as shown on the drawing accompanying Malcolm's patent. The drawing of the furnace as built has been reconstructed and shown in the figure accompanying this paper. It consisted of a deoxidizer, A, and of an ordinary reverberatory or open-hearth furnace, about 17 ft. long, divided into three compartments—B, the balling-furnace; C, the puddling-furnace; D, the fire-grate. The coal used for firing on the ordinary furnace-bars was from Westport and Newcastle. The hot gases from the furnace played direct on the floor of the puddling-furnace C, passed on to the balling-furnace B, then passed through the roof into a central flue F, about 2 ft. in diameter, and were carried up the full length of the deoxidizer, a height of 21 ft.; the gases struck the crown at the top of the furnace, and passed in a downward direction between the retorts R, there being radial spaces F between the retorts for the gases to pass through; on reaching the bottom they were deflected so as to pass upwards (F) on the periphery or outside of the surface of retorts, and between that and a firebrick lining against the shell of furnace. On the gases reaching somewhere near the top they passed out into an annular flue and by way of an iron chimney into the atmosphere.

The deoxidizer held 10 tons of carbon and ironsand. After the silica had been extracted by a magnetic separator it was thoroughly mixed with 20 per cent. to 25 per cent. of coal or charcoal, Taupiri coal being used. The material was hoisted to a platform above the deoxidizer, from which each retort was filled from filling-boxes. It required twenty hours to deoxidize or carbonize the iron by driving out the oxygen. The sand was red-hot, but not so sticky that it would not run through the chutes leading to the balling-furnace, which were controlled by heavy gate-valves.

The deoxidized sand dropped on to the floor of the balling-furnace, where it lay for some thirty minutes, there being a door at the side of the furnace to permit the puddlers to test the condition of the material before balling it. It would work up exactly as cream works into butter, having very much the same appearance. On a ball of about 18 in. diameter being made it was rolled or passed over to the puddling-furnace C, when it was again attacked by a fresh set of puddlers, who vigorously worked it up

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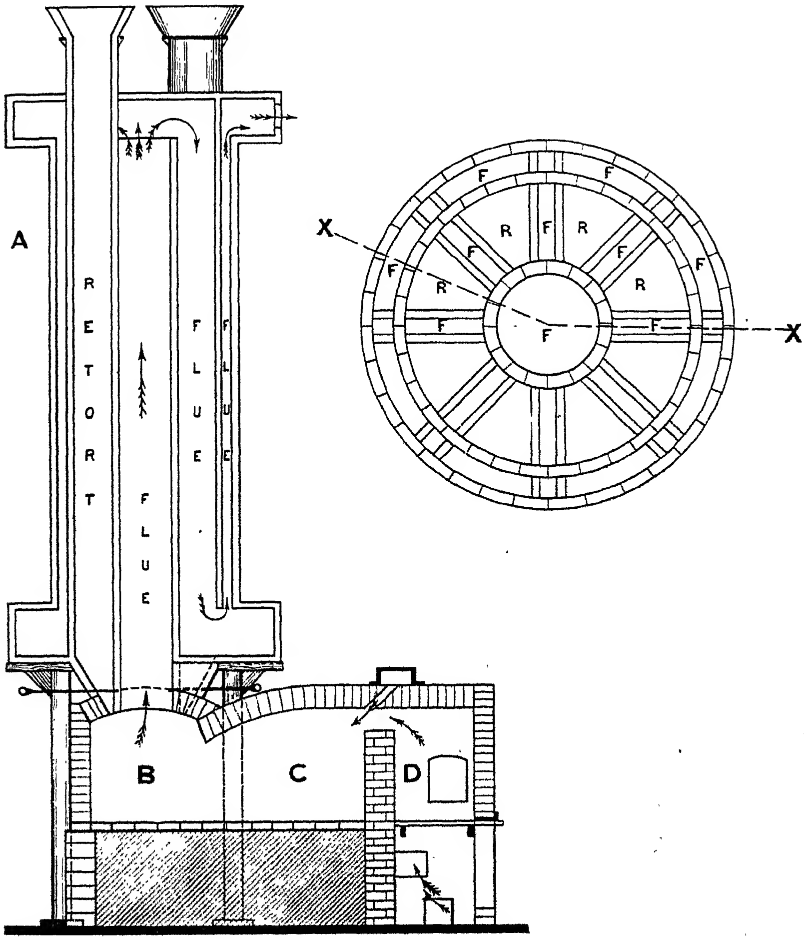
* "Malcolm, R. L.—8th January, 1883—Improvements in furnaces for reducing iron-ores," *N.Z. Pat. Reg.* No. 762.

† "Gardner, G. H.—23rd April, 1883—Improvements in furnaces for the manufacture of bar iron and blooms," *N.Z. Pat. Reg.* No. 818.

until it was ready for the squeezer; or, in the case of the first trials, the ball was placed on the anvil of a steam-hammer and gently squeezed into a square form, after which it could be hammered with the full force of the hammer and drawn into the shape of a billet or bloom.

The cost of the first furnace was £500. It was completed early in February, 1883, and on the 27th the first iron by the new process was



DESIGN OF FURNACE.

A, deoxidizer; B, balling-furnace; C, puddling-furnace; D, fire-grate; F, flues; R, retorts.

made into billets, and it was shown that the quality exceeded all expectations. On the 5th March George Fraser and Sons, Auckland, made three bars, 8 ft. long, 2 in. square, of perfect quality. The furnace, under the charge of W. H. Jones, was kept working for about ten days, and at that time good blooms were produced, which were worked up into bars and thoroughly tested by several leading blacksmiths in Auckland, Mr. George

Leahy making a large double pair of ornamental gates of beautiful design to demonstrate the quality of the iron, which was equal to Netherton Crown.

After a stoppage for some necessary repairs the fires were lit for a second time. The best results obtained from one charge in the deoxidizer was the manufacture of 6,751 lb. of iron from 14,625 lb. of sand; the slag or cinder amounted to 7,215 lb., the loss of cinder and waste in furnace being reckoned at 659 lb., resulting in 46¼ per cent. of iron being produced from the separated sand. The operations were carefully watched by Messrs. James Stewart and Edmund W. Otway, of Auckland, who on the 29th March made the following report:—

"We have the honour to state that, as requested by you, we have attended at your works erected at Onehunga for the reduction of the ironsand, for the purpose of examining in detail the whole process and obtaining data for reporting on the cost of production. We are as yet unable to make a complete report, but hasten to give you a few of the more important results, and the deductions which may fairly be drawn from them. We hope shortly to report in a more exhaustive manner.

"On Monday, the 19th instant, four retorts were filled with a mixture of ironsand and charcoal, in the proportions of one measure of sand to two of charcoal. Other four retorts were filled with a mixture of ironsand and ground Waikato coal, in the proportions of two measures of coal to three of sand, the intention being to put in 20 per cent. by weight of both charcoal and coal in proportion to the sand. The above mixtures give that percentage of coal, but more than that of charcoal, and in subsequent operations in filling up the exact ratio of 20 per cent. was adhered to.

"The fires were lighted on Monday night, and on Wednesday a small charge was tried, but found not sufficiently carbonized or deoxidized—either term appears correct. Puddling was therefore deferred until Thursday, the 22nd, and was then commenced with the coal mixture principally. But it soon became apparent that the coal was not in sufficient proportion to carbonize the ore, and after working all day with a very poor result it was determined to discharge all the coal mixture remaining in the retorts and recharge with charcoal and ore.

"On Friday work was resumed with better success, but, as coal mixture had been used to fill up the shrinkage in the retorts remaining to be worked, its presence still caused trouble, principally by the great amount of slag produced, and iron dry and difficult to work to nature, causing the blooms to be returned to the furnace once, and sometimes twice.

"On Saturday the work went on very well, and if the draught of the furnace had been perfect little could have been desired in the result.

"We have worked out the result in two ways: (1) total sand ore worked by both mixtures, against total yield of iron; (2) discarding the yield of iron on Thursday, when the iron-ore was mixed with the coal, as obviously the fairest view to take. The first result is 38 cwt. of iron from 149 cwt. of sand, equal to 25·5 per cent. (very nearly) of puddled blooms. The second view gives 33·25 cwt. from 98 cwt. of ore, equal to 34 per cent. (nearly) of puddled blooms.

"From the somewhat extemporized nature of the works, we feel confident that the above percentage at least can be maintained by carbonizing with charcoal. And by increasing the coal mixture to an amount equivalent to 20 per cent. of carbon we have reason to believe a like result will be obtained.

"Discarding Thursday's run, the coal used in puddling and keeping up the heat at night on Friday, Saturday, and Monday, including the coal

necessary to keep the furnace hot over Sunday, was 3·21 tons, which works out to 38·6 cwt. per ton of blooms. We feel quite safe in saying that with continuous working the conversion of the ore can be effected at under 30 cwt. of coal per ton of iron, and that all the heat and firing required by the whole process can be supplied by the waste heat from the furnace and retorts in the use of that weight of coal. This is even with the direct use of coal; but with the most improved gas regenerative furnace not only will the amount of coal be very largely reduced, but much inferior fuel may be used.

"Keeping in view all the above points, we have no hesitation in saying that the process has been shown to be profitable, but to what extent we are yet unable to say. We trust, however, that this interim report will be of service to you."

It was estimated the cost of manufacture would be as follows:—

	£	s.	d.
Cost of 3 tons of ironsand at works, at 6s. 8d. per ton	1	0	0
30 cwt. coal at works	1	10	0
Carbon for retorts	0	10	0
Puddling, per ton	1	0	0
Shingling, rolling into puddle-bars, weighing, shearing, piling, reheating, and rolling into 1 in. bars	0	10	0
Engine-driver's time, millwright, bricklayers, &c., and incidental expenses	0	10	0
	£5	0	0
Add 25 per cent. for establishment charges, depreciation on plant	1	5	0
Cost per ton	£6	5	0

When the furnace was working during April the works were visited by Mr. Pearson, of Pearson, Knowles, and Co., of Warrington, who took a great interest in the work, and said the process represented the greatest advance of the present age. At the same time they had another distinguished visitor—Mr. Sydney Gilchrist Thomas, of London, inventor of the basic process which did so much to cheapen the cost of manufacturing steel. He declared that for the first time he had seen wrought iron made direct from ore, and it was what all ironmasters had been trying to do for a century. He was prepared and wished to enter into a contract for the purchase of 5,000 tons of blooms per annum.

As a result of the visits of these two men and the favourable reports obtained from all quarters it was resolved to form a company with a capital of £200,000, made up of 40,000 £5 shares: of these, 9,103 were subscribed by the public, leaving a balance of 30,897; the paid-up capital being £45,515. The total expenditure was about £58,000, the plant and buildings costing £34,329.

The company proposed to order sufficient material and plant for the erection of ten deoxidizers and furnaces. A rolling plant was ordered from Messrs. Walker, Eaton, and Co., of Sheffield, who supplied an 18 in. forge-train with squeezer, pendulum shears, and engines, a 14 in. and 10 in. merchant mill, hot-saw, two shingling-hammers (each of 50 cwt.), and all necessary gear for a complete works to turn out 30 cwt. of bar iron or rolls per day. Four Lancashire boilers and four Wilson gas-producers were

ordered from Tangyes Limited, to provide gas for heating furnaces, firing boilers, &c., it not being proposed to use coal in any furnace or place.

The site on which the experimental furnace was erected was purchased, consisting of about 5 acres on the south-east side of the Onehunga railway-station, from which a siding was run into the works. It had a water frontage, which became valuable by a canal being cut to deep water to enable vessels of light draught to come right into the works, so that Westport or Newcastle coal could be delivered direct. It was a fine site, having many advantages, several springs providing a good supply of fresh water. It was admirably situated for cheap and economical working, for it was intended that the ironsand should be brought from the North Head of Manukau Heads, where a Government lease, of sixty-six years, was obtained for 6¼ miles of beach and 1,000 acres of land, on which there were millions of tons of iron. There was good shelter and deep water at the Heads for loading, it being proved from actual experience that the sand could be raised, trucked, delivered to vessel, and conveyed to works at a cost not exceeding 6s. 8d. per ton. The average sample of ironsand obtained from the Manukau Heads would analyse as follows:—

Iron-oxide	88·88
Titanium	0·30
Lime	Trace
Magnesia	„
Silica	9·98
Loss	0·84
	100·00

Equal to 66·36 per cent. iron.

The patience of the shareholders was somewhat tried by the long wait for machinery to come from Great Britain. Contracts were let for a furnace-house to contain the forge-train, which measured 106 ft. by 100 ft. The roof of this building had a single span. There was also a similar building, 100 ft. square, for the merchant mills and reheating furnaces. Offices, laboratory, carpenters' and engineers' workshops, foundry complete with cupola, set of furnaces for making crucible steel, storage, drying and mixing shed for coal and sand, were all got under way, and, in addition, a brick-kiln, which turned out 200,000 firebricks before the machinery arrived.

The prospects were bright and every one was sanguine of success; but on the 23rd December the company suffered a great blow by Mr. W. H. Jones quarrelling with a bricklayer, whom an hour or two afterwards he shot in the main street of Onehunga, for which he got ten years' hard labour. No suitable man could be obtained from America, and it was thought that Mr. Edmund Otway, an old ironmaster, would fill the position, which he did for some months. He was a very capable man, but unfortunately he broke down and died in June, 1884. This was looked upon as a serious loss, but fortunately the position was filled by Mr. John Heskett, at one time manager of one of Bolckow Vaughan's works at Middlesborough, who proved to be thoroughly capable, and manfully carried on the work. He, unfortunately, had to fight against great difficulties through ill health, and finally broke down at a critical time, when the works were completed and ready to commence operations.

On the 7th November, 1884, the first machinery arrived from England; it was quickly erected, for by the 1st May, 1885, the fires were lit in two furnaces, when it was shown that 1 ton of bars could be made from 3 tons

of 75 per cent. oxide—that is, the sand as found on the beaches. The new furnaces were supplied by gas under forced draught generated by the four Wilson gas-producers, and all worked well for a few days, when it was found that the coal contained too much moisture, which destroyed the heating properties of the gases. Again and again endeavours were made to overcome this difficulty. The fires would be lit in the gas-producers, and the quality of gas for the first few hours would be perfect; but as the furnaces became hot and just about ready for men to work the sand and deoxidizers the heat gradually fell away, or a series of explosions took place, which showed it was time to stop. This was one of the first difficulties met with, and one that was never overcome in spite of many experiments.

By this time the shareholders were becoming impatient, for they wanted to see returns. The loss of two managers, followed by the enforced retirement of Mr. John Heskett, had a good deal to do with the company breaking up.

Mr. James McAndrew, an ironmaster, who had been on the Clyde, accepted the position of manager, and did his best to produce iron from sand, but none of Mr. W. H. Jones's successors could produce iron of the same quality as he did. There were difficulties with the deoxidizers: air seemed to leak through or get into the retorts, resulting in a portion of the sand not being deoxidized, and, although it would work up into a bloom which had the appearance of being good, when passed through the forge-rolls the bars would fracture through the sand not being properly deoxidized or cemented together.

The directors got a rude awakening by receiving a report from Mr. John Coom, which showed that the iron was brittle and could not be sold as a first-class commercial article. The report reads as follows:—

"The iron was tested for tensile strength and by bending; the steel was made into tools and used in wheel-turning and general work.

"Three pieces of the iron (marked 'A' in the schedule) were drawn down to a sectional area of ¼ in.; the two pieces marked 'B' were tested as sent from the works, the section of these being about 1 square inch.

"The apparatus used in testing is not one specially designed for the purpose: the results cannot, therefore, be looked upon as strictly accurate.

"For your information I have shown results of some of Kirkaldy's tests of Bowling and Lowmoor iron, and the specification of the iron supplied for the Ohio (America) railroad bridge.

No. of Piece.	Brand.	Mean Breaking-weight per Square Inch of Original Section.	Contraction of Area at Fracture.	Mean Elongation.
		Tons.	Per Cent.	Per Cent.
1	A	26·00	23·4	7·3
2	A	26·46	25·1	4·1
3	A	31·93	27·6	10·9
4	B	16·26	20·6	8·5
5	B	16·26	4·5	2·7
..	Bowling ..	27·86	45·3	29·4
..	Lowmoor ..	27·59	53·1	26·5
..	Ohio River Bridge specification	26·75	25·0	15·0

"The pieces 1, 2, and 3, which were drawn down from a large section, are superior to the pieces 4 and 5, which were tested in same section as received.

"The results show the iron to be of a hard and unyielding character, but it evidently is improved by working; it would require this before it could be safely used in engineering-works. The mean breaking-weight is high, but the contraction at the fractured area and the elongation are low, showing the iron to be as I state.

"A further test of the iron was made by bending cold, and the results were fairly good: two pieces were bent double and showed but few cracks.

"The steel was made into tools for use in the wheel and other lathes; these were given to the turners with instructions to use them for a week and then report. Their report was very favourable: they say the tools stood as well as most of those made from the imported article."

The company then resorted to manufacturing wrought iron from scrap, but this was not profitable. First-class chemists were engaged in the laboratory, Mr. D. S. Galbraith working very hard in the hope of overcoming difficulties, but this was never done.

The company struggled on until November, 1886, when, with its capital spent and a liability of £20,000, an attempt was made to reconstruct; but the shareholders would not find money, and the assets of the company were taken over by the mortgagee. For a short time it was worked under tribute in the manufacture of bar iron from scrap, but this was never profitable, and finally the plant was broken up and shipped to China, to be used there in new ironworks.

So ended the most serious attempt at manufacturing iron from the sands of New Zealand, and one wonders now why it was not a success. Everything was done that could be thought of at the time by all concerned, for they were sanguine to the last, and hoped to retrieve the fortune spent in endeavouring to create a great industry for the Dominion.

Art. XXV.—*Notes on the Autecology of certain Plants of the Peridotite Belt, Nelson: Part I—Structure of some of the Plants (No. 1).*

By M. Winifred Betts, M.Sc.

Communicated by Professor Benham, F.R.S.

[*Read before the Otago Institute, 9th October, 1917; received by Editors, 29th December, 1917; issued separately, 24th June, 1918.*]

Introduction.

At a short distance from the city of Nelson there is an area known as the "Mineral Belt." This is a zone of boulder-strewn land-surface, often dun-coloured in appearance, underlain by peridotite and serpentine rocks, which extends from D'Urville Island, in Cook Strait, south-west for a distance of sixty miles. It is an almost continuous band, but it disappears for about a mile between the valleys of the Lee and Serpentine Rivers. At its narrowest part the Mineral Belt is 100 yards wide, and it reaches its maximum width of 3 miles 50 chains in the vicinity of the Dun Mountain. The area occupied by the Mineral Belt is about $29\frac{1}{4}$ square miles.*

* J. M. Bell, E. de C. Clarke, and P. Marshall, The Dun Mountain Subdivision, *N.Z. Geol. Surv. Bull. No. 12*, 1911.

The vegetation of the Mineral Belt presents a striking contrast with that of the neighbouring land-surface, which is clothed with luxuriant forests of southern-beech (*Nothofagus* spp.). On the Mineral Belt there are three principal plant-associations :—

1. *Shrubland.*—This is usually found near the margin of the Belt, and is composed of many species that are found in the adjacent forests, but on the Belt they are much dwarfed—*e.g.*, *Griselinia littoralis* is usually a tree 10–16 metres high, but in the shrub formation on the Mineral Belt it is reduced to a woody shrub ⅓–2 metres high; *Nothofagus fusca*, a forest-tree, is represented by small trees 2–3 metres high. In addition to these dwarfed representatives of the neighbouring forests there are in this association a number of shrubs which are not reduced. Such plants are *Cassinia Vauvilliersii* var., *Coprosma propinqua*, *Dracophyllum longifolium* var., and *Leptospermum scoparium* var. In this association there are a number of small herbs—*e.g.*, *Claytonia australasica*, *Colobanthus quitensis*, and *Epilobium pedunculare* var.

2. *Open Scrubland.*—In this association the most characteristic plants are *Cassinia Vauvilliersii* var., *Dracophyllum rosmarinifolium*, *Exocarpus Bidwillii*, *Hymenanthera dentata* var. *alpina*, *Veronica buxifolia* var., *V. Menziesii* var., *V. pinguifolia* (?), *Pimelea Suteri*, and *Muehlenbeckia axillaris*. Among the herbs to be found in this association are *Myosotis Monroi*, *Notothlaspi australe*, *Gentiana corymbifera*, *Anisotome aromatica*, and *A. filifolium*.

3. *Tussock Grassland.*—The dominant plant is *Danthonia Raoulii* var.; sub-dominant are *Phormium Cookianum* and *Astelia montana* var.

It is proposed to describe the anatomy of a number of the plants of the Mineral Belt in a series of short papers, and then the results obtained from these investigations will be considered.

In addition to the anatomy of the leaf and of the stem of the different species, a brief description of the growth-form of the plant is given. In those cases where the usual form of the species is found on the Mineral Belt this description is quoted from Cheeseman's *Manual of the New Zealand Flora* (1906). Where the species is modified in form, a description of the usual type is quoted, and then that of the plant as it is found on the Mineral Belt is given.

1. Nothofagus fusca Oerst.

Usual Growth-form.—"A noble forest-tree 60–100 ft. high; trunk 4–8 ft. diam.; bark dark-brown or black in old plants, deeply furrowed, smooth and greyish-white on young trees; branchlets and petioles pubescent. Leaves evergreen, petiolate, ¾–1½ in. long, broadly ovate or ovate-oblong, obtuse or rarely acute, cuneate at the base, rather thin but firm, pubescent above and glandular beneath when young, glabrous when old, deeply and sharply serrate, veins conspicuous; stipules linear-oblong, caducous."

Mineral Belt Growth-form.—A small tree 6–8 ft. high, with leaves ½–¾ in. long.

Anatomy.

Leaf.—The upper epidermis consists of small cells, more or less oval in transverse section. The cell-walls are thin, except the external walls, which are slightly thickened and also cuticularized. Some of the epidermal cells, in the vicinity of the vascular bundles, are produced into long unicellular hairs which have thin, slightly cutinized walls. There are no stomates on the upper surface.

The lower epidermal cells are small, oval, and thin-walled, the external walls being slightly thickened. A thin cuticle is present. Stomates are

confined to the lower surface; the guard-cells are small and on the same level as the other epidermal cells, the stoma being protected by guard-cell ridges. On the lower surface there are hydathodes, which are sunk in slight depressions.

The chlorenchyma is differentiated into palisade and spongy tissue. The former consists of 3 rows of thin-walled cells, the outer layer with the cells very closely arranged so that there are no intercellular spaces; the 2 inner layers are arranged more loosely. The spongy tissue consists of small thin-walled irregular cells which have rather small air-spaces between them. Many of the chlorenchymatous cells contain tannin.

The midrib is slightly prominent. Surrounding the vascular bundle of the midrib there is a sheath 1–3 cells thick, consisting of small sclerenchymatous cells. Around this there is a sheath of larger cells, also with lignified walls. The xylem consists of vessels of moderately large diameter and of wood-fibres. Above the xylem there is a small amount of parenchyma. The phloem is in the form of a crescent; the parenchymatous elements contain tannin.

Stem.—The cork is a fairly wide band of tissue, consisting of small, very compact cells.

The cortical cells are large, and oval in transverse section. These cells are thick-walled, and many of them contain tannin. They are closely arranged, so that there are only small intercellular air-spaces.

The pericycle fibres form a wide band, in which the cells vary considerably in size in transverse section. Some are small, with their cell-walls so much lignified and thickened that the lumen is almost obliterated; connecting groups of these cells are much larger cells, also with thickened, lignified walls, but the cell-cavities are large.

The phloem forms a narrow band, and the parenchyma contains tannin. The spring wood consists of a large number of vessels of large diameter, together with wood-fibres. The autumn wood is formed of much smaller vessels, and of wood-fibres in which the lumen is almost obliterated.

The medullary rays are uniseriate, and the cells have thickened lignified walls, and contain tannin. The pith cells are large and round, have thickened lignified walls, and contain abundant starch.

2. Nothofagus cliffortioides Oerst.

Usual Growth-form.—"A small tree, usually from 20 ft. to 40 ft. high, rarely more, with a trunk 1–2 ft. diam., in alpine localities often dwarfed into a much-branched bush 5–12 ft. high. Branches spreading, often distichous, especially in young trees; branchlets densely pubescent. Leaves shortly petiolate, distichous, $\frac{1}{6}$–$\frac{2}{3}$ in. long, ovate-oblong or ovate or ovate-orbicular, acute or subacute, rarely obtuse, always broadest at the unequally rounded or almost cordate base, quite entire, very coriaceous, glabrous and reticulated above, more or less clothed with greyish-white appressed hairs beneath, margins thickened, often recurved; stipules membranous, caducous."

Mineral-Belt Growth-form.—A much-branched bush 4–8 ft. high, with leaves $\frac{1}{6}$–$\frac{3}{4}$ in. long.

Anatomy.

Leaf.—The upper epidermis consists of small cells which are more or less square in transverse section. These have their cell-walls thickened, and there is a thick cuticle. Some of the epidermal cells contain tannin. On the upper surface there are numerous glands which are formed from epidermal cells.

The palisade and the spongy parenchyma, the lower epidermis, and the stomates are the same as in *N. fusca*, but on the lower surface some of the epidermal cells are produced into unicellular hairs, which have thin non-cutinized walls. There is a thick cuticle on the lower surface. Many of the mesophyll cells and the cells of both the lower and the upper epidermis contain tannin.

The vascular bundles are the same as in *N. fusca*, but the midrib is smaller.

Stem.—The structure is essentially the same as in *N. fusca*, the only differences being—(1) There are more pericycle fibres; (2) the phloem forms a wider band; (3) the pith cells do not contain starch; (4) there are more numerous vessels of large diameter.

3. Exocarpus Bidwillii Hook. f.

Growth-form.—"A small much-branched rigid procumbent shrub 6–24 in. high, branches ascending, short, stiff, terete, deeply furrowed. Leaves reduced to minute triangular scales, alternate, persistent."

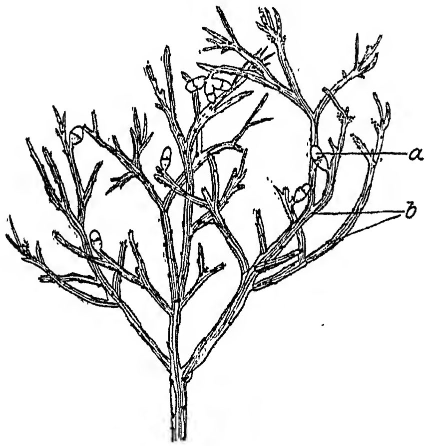


Fig. 1.—*Exocarpus Bidwillii.* Portion of plant (½ natural size). *a*, fruit; *b*, leaves reduced to triangular scales.

A portion of the plant is shown in fig. 1, which also shows the fruit, which is seated on the much-enlarged thickened red and succulent peduncle. The perianth-segments are persistent under the fruit.

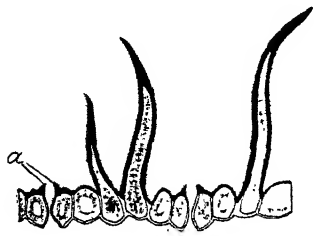
Anatomy.

Stem (figs. 2–4).—The structure of the stem is shown roughly in fig. 2. From this it will be seen that the furrows are lined with stiff hairs, that there is a thick cuticle, &c. The more detailed structure of the stem is shown in fig. 4.

The epidermis consists of small squarish cells with thin cell-walls and an extremely thick cuticle. In the furrows the epidermal cells are larger and there is only a thin cuticle. Many of the epidermal cells in the furrows are produced into stiff hairs, which have thick walls which are cuticularized. In the furrows are the stomates, but these cannot be seen well in transverse section, as their long axes are placed transversely to the surface of the stem.

Fig. 3 gives the epidermis from a longitudinal section; from this it will be seen that the stomates are at the same level as the epidermal cells, and the opening is protected by guard-cell ridges.

The cortex is composed of closely packed more or less polygonal cells with thin walls. In the outer part of the cortex, and especially in the



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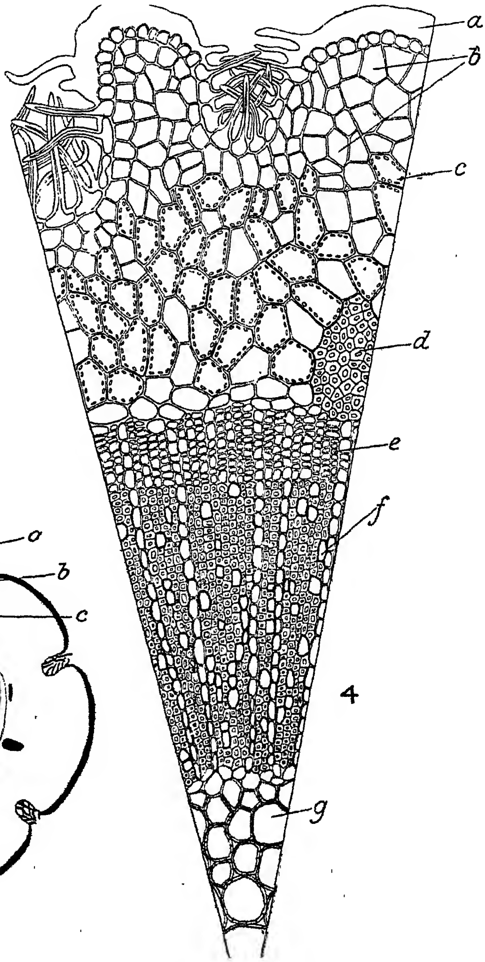

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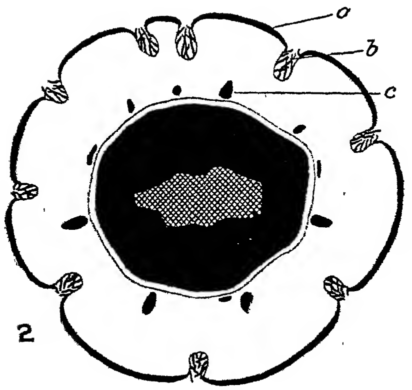

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FIG. 2.—*Exocarpus Bidwillii.* Diagrammatic transverse section of the stem (× 24). *a*, thick cuticle; *b*, furrow lined with hairs; *c*, pericycle fibres.
FIG. 3.—*Exocarpus Bidwillii.* Longitudinal section through epidermis (× 350). *a*, guard-cell ridge.
FIG. 4.—*Exocarpus Bidwillii.* Transverse section of stem (× 120). *a*, thick cuticle; *b*, tannin-containing cells; *c*, chlorenchyma; *d*, pericycle fibres; *e*, phloem; *f*, vessels of xylem; *g*, lignified pith.

ridges, the cortical cells contain tannin: in the inner part of the cortex most of the cells contain numerous chloroplasts, but some contain tannin. At intervals there are large groups of pericycle fibres, composed of small cells with very thick lignified walls and small lumen.

The phloem forms a wide band in which the elements are very regularly arranged. Most of the parenchymatous cells of the phloem contain tannin. The xylem consists chiefly of wood-fibres of small diameter; these have very thick walls and small lumen. The number of vessels is small in comparison with the amount of wood, and they are not of wide diameter. The medullary rays are numerous and uniseriate; the cells have lignified walls, and contain tannin. The pith is solid, and consists of polygonal or roundish cells with pitted lignified walls.

4. Muehlenbeckia axillaris Walp.

Growth-form.—"A small much-branched prostrate or diffuse shrubby plant, usually forming densely matted patches 3–12 in. diam., but sometimes open and straggling; stems and branches woody; branchlets puberulous. Leaves on rather long petioles, small, $\frac{1}{10}$–$\frac{1}{3}$ in. long, broadly oblong or ovate-oblong or almost orbicular, obtuse or retuse, rounded at the base, flat, quite glabrous, dotted beneath."

Anatomy.

Leaf.—The upper epidermis consists of large cells with thin walls, except the external ones, which are slightly thicker. There is a very thin cuticle. The epidermal cells form mucilage-sacs. The lower epidermis is similar to the upper. A few stomates are found on the upper surface, but they are much more numerous on the lower surface; the guard-cells are small and are level with the other epidermal cells. On both surfaces of the leaf there are hydathodes, which are sunk in small depressions; they are more numerous on the lower than on the upper surface.

The chlorenchyma is differentiated into palisade and spongy tissue. The palisade tissue is found on both surfaces of the leaf; there are 3–4 layers of cells on each side. The cells are small, their walls are thin, and they contain numerous small chloroplasts. The outer layers contain tannin. The cells are closely packed, so that there are only very small intercellular air-spaces. The spongy tissue consists of fairly large cells with thin walls and containing numerous small chloroplasts. The air-spaces in this tissue are larger, and some of the cells contain tannin.

The vascular bundles are frequent, but of small size. Above the xylem there is some stereome, and above this small-celled parenchyma. There is also small-celled parenchyma below the phloem. Each vascular bundle is surrounded by a sheath of large parenchymatous cells, which contain tannin.

Stem.—The cork forms a fairly wide zone of very small compact cells.

The cortex consists of oval cells which are closely packed together, so that there are only very minute intercellular air-spaces. Most of the cells contain tannin.

The pericycle fibres form a narrow, more or less continuous band 1–2 cells wide. The cells are small, and have thick walls and small lumen. The phloem forms a wide band, in which the parenchymatous cells contain tannin. The xylem consists almost entirely of wood-fibres, but there are a few vessels of large diameter.

The medullary rays are multiseriate and are very wide. They consist of small cells with thickened lignified walls, and they contain abundant large starch-grains.

The pith consists of rounded or polygonal cells with thick lignified walls. They are closely packed together, and are full of large more or less polygonal starch-grains, and some contain tannin.

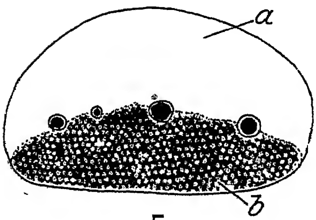
5. Claytonia australasica Hook. f.

Usual Growth-form.—" A perfectly glabrous tender and succulent usually matted plant, with slender creeping stems 1–6 in. long. Leaves very variable in size, $\frac{1}{4}$–$1\frac{1}{2}$ in. long, alternate or in distant pairs, narrow-linear or linear-spathulate, obtuse, dilated into broad membranous sheaths at the base."

Mineral Belt Growth-form.—In the Mineral Belt plants the leaves are $\frac{1}{4}$–$\frac{1}{3}$ in. long.

Anatomy.

Leaf (figs. 5 and 6).—The upper and the lower epidermis are similar; the epidermal cells are large and have thickened walls. A very thin cuticle is present. Stomates are confined to the upper surface of the leaf.



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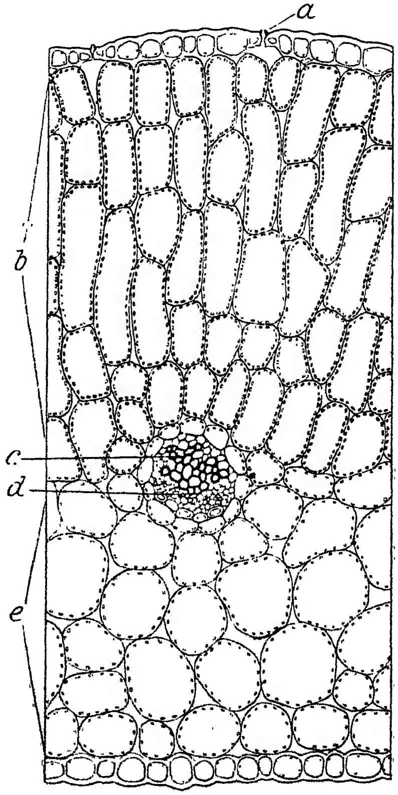

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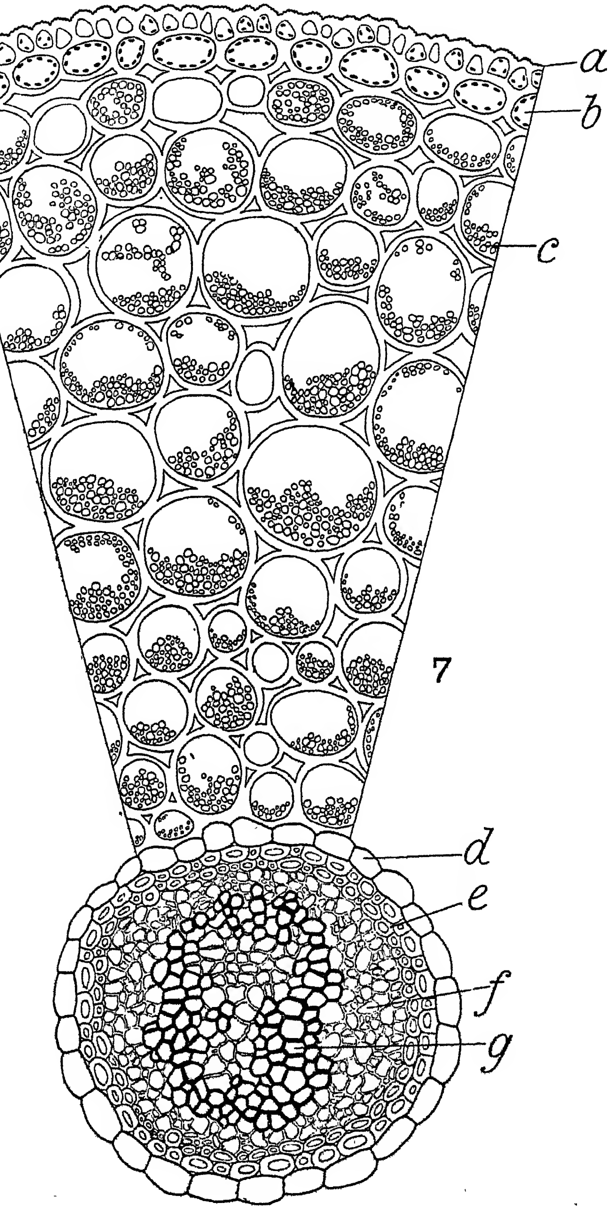
FIG. 5.—*Claytonia australasica.* Diagrammatic view of leaf (× 40). *a*, palisade tissue; *b*, aqueous tissue.

FIG. 6.—*Claytonia australasica.* Transverse section of leaf, passing through midrib (× 160). *a*, guard-cell ridge; *b*, palisade tissue; *c*, xylem; *d*, phloem; *e*, aqueous tissue.

The guard-cells are at the same level as the other epidermal cells, and the opening is protected by guard-cell ridges. The cells of the epidermis contain a few small chloroplasts.



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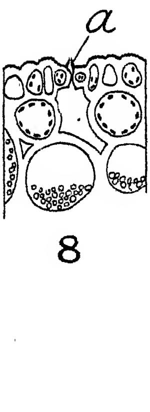

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FIG. 7.—*Claytonia australasica.* Transverse section of prostrate stem (× 210). *a*, ridged cuticle; *b*, chlorenchyma; *c*, starch-grains; *d*, endodermis; *e*, pericycle; *f*, phloem; *g*, xylem.

FIG. 8.—*Claytonia australasica.* Transverse section of the outer part of stem, showing a stoma (× 210). *a*, guard-cell ridge.

The chlorenchyma is differentiated. The palisade tissue consists of about 5 layers of somewhat irregular cells. These cells are very large and are compactly arranged, so that there are only small intercellular air-spaces. The cells contain a large number of small chloroplasts.

The spongy tissue is composed of very large thin-walled more or less rounded cells, with a thin peripheral layer of protoplasm in which are embedded the small chloroplasts. This tissue is for water-storage. There are frequent air-spaces in it, but they are small compared with the size of the cell.

The vascular bundles are small, and are surrounded by a sheath of parenchymatous cells which have thin walls and which contain a few chloroplasts. The xylem and the phloem are of the usual type. The amount of lignified tissue is small.

Stem (figs. 7–8).—The epidermis consists of small somewhat dome-shaped cells which have very thick walls and which contain a few small chloroplasts. A ridged cuticle is present. The stomates are not numerous; the guard-cells are smaller than the other epidermal cells, and the opening is protected by guard-cell ridges (fig. 8).

Below the epidermis there is a single layer of large cells which contain numerous chloroplasts and which have thickened cell-walls. The rest of the cortex is a very wide zone consisting of large round cells with very thick walls and with air-spaces between them. These air-spaces are small compared with the size of the cells. These cells contain a large number of starch-grains, which are heaped at the base of the cell.

There is a well-marked endodermis, consisting of cells with thin suberized walls. The pericycle also is well marked; it is composed of 2 layers of smaller cells with thickened cell-walls.

The xylem is composed of wood vessels which form a more or less continuous cylinder, with a few small parenchymatous pith cells in the middle. The phloem forms a continuous band round the xylem and contains a fair amount of parenchyma.

6. Colobanthus quitensis Bartl.

Growth-form.—"A small densely tufted much-branched plant 1–2 in. high, forming rather soft rounded patches. Leaves variable in size, lower sometimes over ½ in. long, upper often very small, ⅛–¼ in., narrow-linear or linear-subulate, acute or mucronate but not acicular at the tip, connate at the base, flat or concave above, convex beneath; texture soft."

Anatomy.

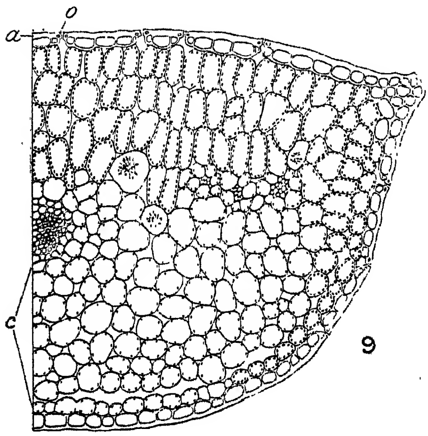
Leaf (fig. 9).—Fig. 9 shows a transverse section of half the leaf. The upper epidermis consists of cells which in transverse section are fairly large and oval. The lateral and the internal walls are thin, but the outer walls are very much thickened. There is no cuticle. The lower epidermis is similar to the upper, except that the cells are slightly smaller and their external walls are not so thick. Stomates are found on both surfaces, but they are more numerous on the upper. The guard-cells are small, have thickened walls, and are raised above the other epidermal cells, but are below their thickened external walls.

The chlorenchyma is differentiated. The palisade tissue consists of about 3 layers of cells, containing numerous small chloroplasts. The cells are more or less oval in transverse section, and have thin walls; the intercellular air-spaces are small.

The spongy tissue consists of fairly large roundish cells which have very thin walls and which contain only a few small chloroplasts. There are fair-sized air-spaces between the cells of the spongy tissue, which forms a water-storage tissue. A few of the cells of the chlorenchyma contain crystal aggregates of calcium oxalate.

The vascular bundles are small, and have only a small amount of lignified tissue. Each bundle is surrounded by a sheath of parenchymatous cells, which contain a few small chloroplasts.

Stem (fig. 10).—The epidermis is composed of more or less rounded cells with thick cell-walls. A ridged cuticle is also present. Inside this layer there is a zone of tissue 5 or 6 cells deep; these cells are empty, have thickened walls, and near the outside are regular in shape, but towards the inside are more irregular. The innermost cells of this tissue are suberized.



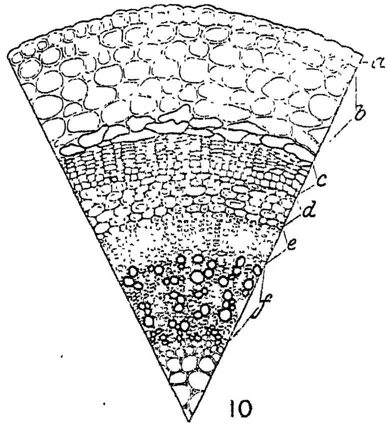


FIG. 9.—*Colobanthus quitensis.* Transverse section of half of leaf (× 125). *a*, thick cuticle; *b*, small raised stoma; *c*, aqueous tissue.

FIG. 10.—*Colobanthus quitensis.* Transverse section of stem (× 125). *a*, epidermis; *b*, dead cortex; *c*, suberized tissue; *d*, thick-walled cortex: *e*, phloem; *f*, xylem.

Next comes a band of small suberized cells. The 2 innermost layers of these cork cells are practically square, but the remainder of this band is composed of the usual flattened cork cells. All the cells of this tissue have thin walls.

The cortex consists of small cells with very thick mucilaginous cell-walls and small cavities.

The phloem forms a continuous wide band around the xylem; the cell-walls are thickened and mucilaginous. The xylem consists of vessels of fairly large diameter, together with a large amount of xylem parenchyma.

The pith is small and solid, and consists of rounded or polygonal cells which are closely packed together, so that there are only minute air-spaces between the cells.

7. Clematis Colensoi Hook. f. var. rutaefolia Hook. f. (?).

Growth-form.—A woody liane with slender flexuous branches. The stems and branches are glabrous, but silky at the tips. The leaves are biternate, with the secondary leaflets stalked. The leaves are slightly coriaceous.

Anatomy.

Leaf.—Both the upper and lower epidermis consist of large cells, somewhat rectangular in transverse section; the walls are slightly thickened, the external ones more so. A thin cuticle is found on both surfaces. Stomates are confined to the lower surface. The guard-cells are large and thick-walled, and are at the same level as the other epidermal cells.

The chlorenchyma is differentiated. The palisade tissue consists of about 3 layers of large irregular cells, which are somewhat loosely arranged, so that there are moderately large air-spaces between the cells. The spongy tissue consists of very irregular cells, which are loosely arranged. Both palisade and spongy tissues contain numerous fairly large chloroplasts.

The vascular bundles are small, and each is surrounded by a sheath of small thin-walled parenchymatous cells which contain a very few chloroplasts. Associated with both ploem and xylem is small-celled parenchyma. The amount of lignified tissue is small.

Stem.—The epidermis is composed of somewhat squarish cells with thickened cell-walls. A moderately thick cuticle is present. Some of the epidermal cells contain a few chloroplasts. Stomates are frequent, the guard-cells, which have thickened walls, being at the same level as the other epidermal cells.

The cortex consists of roundish or irregular cells. This tissue can be divided into two regions—an outer one containing numerous chloroplasts, and an inner colourless region. The cells of the chlorenchyma are rounded or irregular, and their walls are slightly thickened. The colourless cortex consists of somewhat squarish cells regularly arranged.

There are 6 vascular bundles, with a mass of pericycle fibres above the phloem.

The pith is solid, and consists of thin-walled parenchymatous cells. The medullary rays are wide, and are composed of large round or polygonal cells with thickened lignified walls.

8. Notothlaspi australe Hook. f.

Growth-form.—A small densely tufted alpine herb, 2–4 in. in height. It is "usually much branched from the base; branches leafy, spreading, 1–4 in. long. Leaves radical and cauline, numerous, $\frac{1}{2}$–$1\frac{1}{2}$ in. long, petiolate, linear- or oblong-spathulate, entire or crenate, glabrous or with a few cellular hairs."

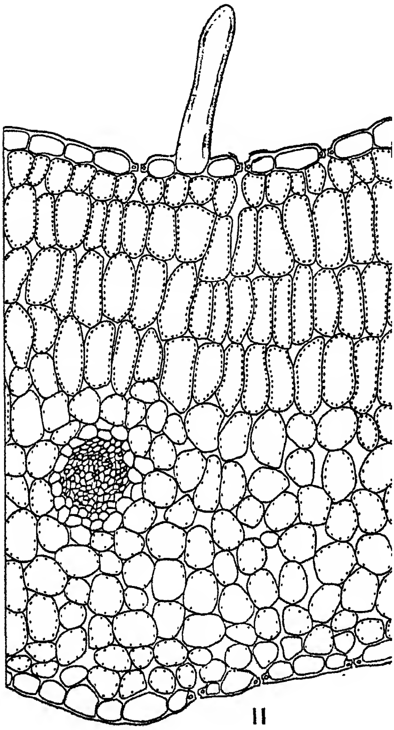
Anatomy.

Leaf (figs. 11–12).—The cells of both the upper and the lower epidermis are large, and oval in transverse section, and have their external walls thickened. There is a thin cuticle on both surfaces. Stomates are very numerous on both surfaces; on the upper surface of the leaf they are slightly sunken, but not on the lower. The guard-cells are small and have their walls thickened. On the younger leaves there are some hairs; on the older leaves there are a few on the lower part of the blade. The hairs are large, thin-walled, and slightly cutinized at their base. They contain protoplasm, and are probably water-absorbing hairs. They are shown in fig. 12.

The chlorenchyma is differentiated. The palisade tissue consists of 4 layers of cells, the layer adjacent to the epidermis being composed of roundish cells and the other 3 layers of large elongated cells. Chloroplasts are numerous but small. There are small intercellular air-spaces between the cells. The cell-walls are thin.

The spongy tissue consists of large thin-walled roundish cells which contain only a few very small chloroplasts, and which form a water-storage tissue.

The vascular bundles are small, and each is surrounded by a sheath of small parenchymatous cells. There are very few vessels in the xylem, and these are of small diameter.



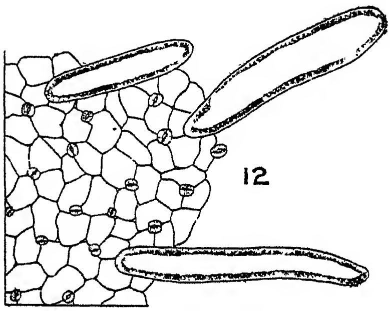


FIG. 11.—*Notothlaspi australe.* Transverse section of leaf (× 100).
FIG. 12.—*Notothlaspi australe.* Upper epidermis of leaf (× 100).

Stem (figs. 13–15).—The epidermis is composed of large cells, which have thin lateral and internal walls, but the external walls are slightly thickened. There is a thin cuticle. Some of the epidermal cells are considerably larger, and form special water-storage cells.

Beneath the epidermis there is a single layer of rounded cells, which contain numerous chloroplasts. The remainder of the cortex, which is a very wide zone, consists of very large round cells with thin cell-walls. All the cortical cells except the outermost layer form an aqueous tissue. The intercellular air-spaces are small.

The phloem and the xylem form continuous cylinders. The amount of lignified tissue in the xylem is small, and there is a moderately large amount of parenchyma in both the xylem and the phloem.

The pith is solid, and consists of large rounded thin-walled cells, which form an aqueous tissue.

Fig. 13 gives a schematic view of a transverse section. There are 3–5 furrows in the stem, and beneath these furrows there are zones of smaller-celled tissue in which the cells are closely packed together and contain small chloroplasts, especially at the corners (see fig. 14).

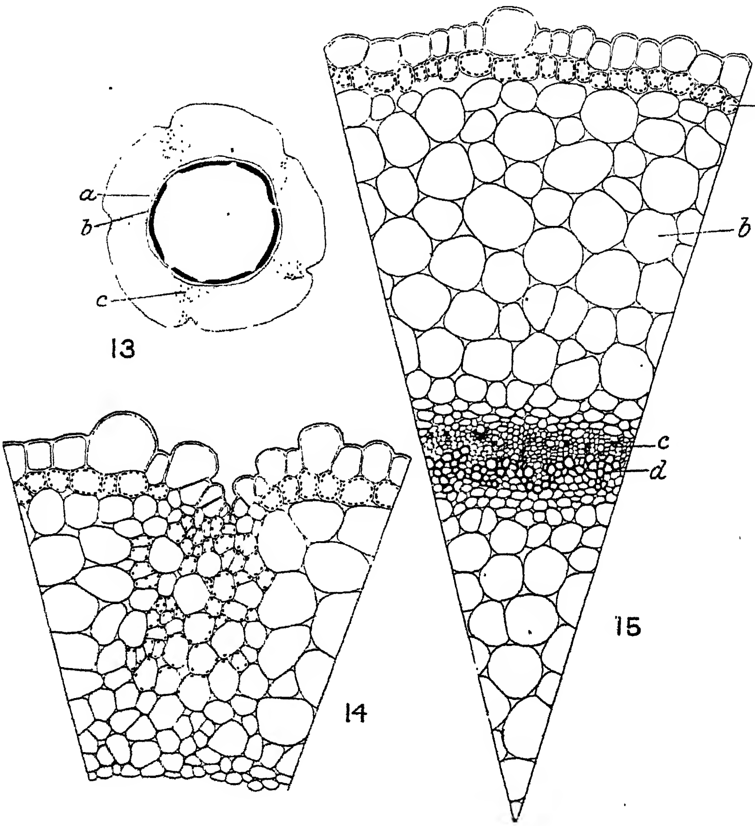


FIG. 13.—*Notothlaspi australe.* Diagrammatic view of a transverse section of the stem (× 20). *a*, phloem; *b*, xylem; *c*, small-celled tissue beneath furrows.

FIG. 14.—*Notothlaspi australe.* Transverse section of cortex below furrow (× 90).

FIG. 15.—*Notothlaspi australe.* Transverse section of stem (× 90). *a*, chlorenchyma; *b*, aqueous tissue; *c*, phloem; *d*, xylem.

9. Weinmannia racemosa Linn. f.

Usual Growth-form.—"A tree 50–80 ft. high or more, with a trunk 1–4 ft. diam.; glabrous when mature, except the raceme, which is pubescent. Leaves of young plants pinnately 3–5-foliolate, thin and membranous, often pubescent; of mature plants 1-foliolate, 1–4 in. long, oblong-lanceolate or oblong-ovate to orbicular-ovate, obtuse or subacute, coarsely and obtusely serrate, very coriaceous, quite glabrous."

Mineral Belt Growth-form.—A shrub 4–8 ft. high,

Anatomy.

Leaf.—Both the upper and the lower epidermis consist of small cells which in transverse section are oblong. The cell-walls are thin, but the lateral and external walls are cutinized. The cuticle is smooth and fairly thick. Stomates are confined to the lower surface. The guard-cells are at the same level as the other epidermal cells, and the stoma is protected by guard-cell ridges.

Below the upper epidermis there is a hypoderma composed of 2 rows of large cells with thick walls. These cells contain tannin. Above the lower epidermis there are 1–2 broken layers of hypodermal cells; these in transverse section are more or less rounded, have thick walls, and contain tannin.

The chlorenchyma is differentiated. The palisade tissue consists of 3 rows of cells with thin walls and numerous chloroplasts. The two outer layers are very compact, but the third layer has fairly large air-spaces between the cells. The spongy tissue consists of irregular thin-walled cells with abundant chloroplasts. These cells are loosely arranged, so that there are large intercellular air-spaces.

The midrib is prominent. Above and below it the epidermal cells are smaller and the hypoderma is thickened. On the lower surface there is collenchyma. Below the hypoderma there are a few small cells, which contain chloroplasts. The vascular bundle forms an irregular cylinder, in the centre of which there are round cells with lignified walls. The xylem consists of vessels of small diameter and of wood-fibres. The phloem is a narrow zone formed of small cells. Outside the phloem there is a narrow band of small sclerenchymatous cells with thickened walls.

Stem.—The cork is a wide band of tissue in which the cells are large and irregular. The phellogen is well marked.

The cortex consists of oval cells with thick walls. These cells contain abundant starch-grains, and are compactly arranged, so that there are only small intercellular air-spaces.

The pericycle fibres form a continuous band around the phloem. These fibres vary considerably in diameter, and have their walls very much thickened, so that the lumen is small.

The phloem forms a fairly wide band with numerous uniseriate medullary rays which contain tannin passing through it. The xylem is well developed, and is composed of vessels of fairly large diameter and of wood-fibres with thick walls and small cell-cavities.

The medullary rays are numerous and are uniseriate, and have thickened lignified walls, except in the phloem, where the walls are not lignified. The pith is solid and consists of roundish cells with thickened lignified walls. The cells contain abundant starch-grains and are closely packed together, so that there are only very small intercellular air-spaces.

Art. XXVI.—*The Succession of Tertiary Beds in the Pareora District, South Canterbury.*

By M. C. Gudex, M.A., M.Sc.

[*Read before the Philosophical Institute of Canterbury, 1st December, 1915; received by Editors, 31st December, 1917; issued separately, 24th June, 1918.*]

Plates XVI, XVII.

Contents.

Field-work and Acknowledgments.

The field-work on which this paper is based was carried out prior to October, 1914, but illness prevented the completion of the paper for publication at that time. Since then the interesting discoveries made by Messrs. Speight and Thomson in the Castle Hill Basin and by Professor Marshall at Wangaloa have thrown new light on the classification and correlation of the younger rocks of New Zealand, and a more detailed examination of the lower beds in the Pareora district has become desirable. I hope to make additional collections from these beds in 1918.

My thanks are due to Mr. H. Suter for assistance in the identifications of fossils, to Dr. Thomson for the identification of the brachiopods from the limestones and for much help in the arrangement of this paper, and to Mr. R. Speight for the assistance and encouragement so freely given at all times.

Introduction.

Although the Pareora district was one of the earliest to be visited as a locality for fossils, and has given its name to one of the main divisions of the New Zealand Tertiaries in older classifications, no careful examination has hitherto been made of its stratigraphy. Its geology, in addition, presents other features of great interest, in which are included the physiography and structure, the existence of a great sheet of dolerite, and the presence of thick deposits of yellow clay considered to be a loess. The present paper deals only with the stratigraphy of the Tertiary beds, and covers the area between the Otaio and Tengawai Rivers.

The first geologist to visit the district was W. Mantell (1850), who traversed the coastal part on his journey from Christchurch to Dunedin in 1848. He mentions the presence of a vesicular volcanic rock at Timaru, and states that he was informed that a bed of coal, 10 ft. thick, cropped out on the banks of a stream inland of Timaru.

Haast in 1865 examined the country between Mount Horrible and Timaru, and the banks of the Pareora River, with a view to obtaining a water-supply for Timaru. The Tertiary beds are described as consisting of tufaceous limestones, calcareous sandstones, and marly and argillaceous

beds alternating with each other for many hundred feet, and are correlated with the Curiosity Shop series of Middle Tertiary age. The prominent dolerite sheet which extends from the summit of Mount Horrible to Timaru is compared with that of the Harper Hills, and it is considered as closing the marine deposits of the district. An earlier eruption of dolerite, forming an intercalation in the marine series, is stated to outcrop on the western slopes of Mount Horrible.

In 1873 Hutton, in his *Catalogue of the Tertiary Mollusca*, &c., introduced the Pareora formation as one of the four chief divisions of the Tertiary, dividing it into an upper and a lower group, but he identified no fossils from Pareora, and was uncertain whether this locality should be referred to the upper or lower group. The reasons for the choice of the name for the formation are quite obscure.

McKay in 1877 visited the Pareora district in the course of an examination of the younger rocks skirting the Canterbury Plains between Waipara and Oamaru. The succession is described in terms of the Cretaceo-Tertiary succession of the Waipara district. From his account, together with a section through the district from north-west to south-east, the following succession may be pieced together: (1) The silts of the Timaru Downs; (2) older gravels, with sands and lignites, resting unconformably on (3); (3) grey sands, with beds of shells, overlying dark-blue sandy beds with concretions (Pareora beds); (4) light-grey marly sandstone (grey marls); (5) calcareous greensands (Weka Pass stone); (6) chalky limestone (Amuri limestone); (7) sharp grey quartzose sands, with occasional beds of pebbles, often containing sharks' teeth (concretionary greensands, saurian beds, &c.). The junction between the Pareora beds and the so-called "grey marls" was not observed, but an unconformity is presumably indicated by the absence of the Mount Brown beds of the Waipara succession.

In 1905 Park, in discussing the relations existing between the Pareora and Oamaru series, referred briefly to the Pareora district. He considered the sections at the lower and upper ends of the Pareora Gorge as too obscure to be of value for the determination of the relations between the beds containing the "Pareora fauna" and the Oamaru stone, and stated that at White Rock River the fossiliferous clays and sandstones there exposed rest on the basement rock of the district. Lists of fossils from the sandstones of the Pareora River at the lower end of the gorge, the bluish-green sandy clays at White Rock, and the limestone on the south bank of the Tengawai River near Cave are given, the latter being correlated with the Mount Brown beds.

Park's general conclusion was that the Pareora series was an integral part of the Oamaru series, which when completely developed includes two limestones separated by the Hutchinson Quarry and Awamoa beds, and that the Pareora fauna is only found in beds underlying the Waitaki stone, to which all the limestones in South Canterbury are apparently referred.

In 1908 Hardcastle published a small pamphlet on the geology of South Canterbury, in which the Tertiary rocks are dealt with more from a point of view of climate than of general stratigraphy. The lowest beds, the coal-measures, are comparatively thin, consisting of white or pale-coloured clays, beds of sand (usually white, of all degrees of fineness and coarseness), white grits and gravels of quartz, and seams of coal or lignite. The climate was considered to be mild, without frost, allowing a luxuriant vegetation to flourish, and the above beds were considered as terrestrial, the whiteness

of the rocks being largely due to the bleaching properties of the humous acids of the soil. Subsidence then ensued, with deposition of marine sandstones which are red in colour, followed by a growth of coral reefs resulting in limestones, the climate still remaining mild. Elevation now occurred, and new terrestrial beds were formed by a rewash of the older marine beds, such rearranged sands with marine fossils being recognized in a bore well at Timaru. The climate now became colder, culminating in a glacial age, during which the older red gravels were accumulated. A warmer period then ensued, during which a soil formed on the older gravels, preserved under the dolerite-flow of Mount Horrible. This was followed by a second glacial age, during which the loess was formed on the surface of the dolerite.

Thomson in 1914 made some observations on the Waihao district which have an intimate bearing on the neighbouring Pareora district. Briefly stated, he concluded that in South Canterbury and Otago there are not two limestones separated by beds with the "Pareora fauna," as Park in 1905 supposed, but one limestone separating two sets of beds with the "Pareora fauna," and suggested that these two similar faunas must show some differences when carefully examined.

Marshall in 1916 described a specimen of the lower chalky limestone of the Otaio Gorge, and, arguing from the presence in it of *Amphistegina*, correlated it with the Amuri limestone. Thomson in 1917 disputed this correlation, on the grounds that the Otaio limestone overlies rocks with an Oamaruian fauna, while the Amuri limestone everywhere overlies rocks with a Cretaceous fauna and contains a lower Oamaruian fauna in its uppermost part in the Castle Hill Basin.

My examination of the district shows that the Tertiary beds of the district are all conformable, and not separable into two unconformable groups as McKay supposed; that the upper beds with a "Pareora fauna" are above the limestone, and not below it as Park supposed; and that there is a similar fauna above and below the limestone, as Thomson suggested. I agree further with Thomson that the lower chalky limestone of the Otaio River is not the correlative of the Amuri limestone, but represents a higher horizon. The differences between the fossils above and below the limestone may be gleaned from the tables appended to this paper, but it is not advisable to draw far-reaching conclusions as to the zonal values of the fossils which have a restricted range in this district, until similar lists from the neighbouring Kakahu, Waihao, Waitaki, and Oamaru districts are available.

General Description of the Stratigraphy.

The complete sequence of Tertiary beds in the Pareora district may be resumed in tabular form as follows:—

		Ft.	
Red sands and sandstones	..	400	Pareora series.
Blue clay	..	350	
Limestone	..	80	Oamaru series.
Crab-beds and marls ..	..	100	
Lower sands and sandstones	..	100	
Coal-measures ..	..	300	

This really represents the average thickness as seen in the different localities, but it is probably a low estimate. The blue clay may never be more than 350 ft. thick, but the other members are sometimes much

thicker than shown above. Thus the limestone sometimes reaches 120 ft., and the upper red sands may reach as much as 500 ft. The quartz grits also are frequently thicker than in the table; this is seen in the foothills between White Rock and Squire's Farm.

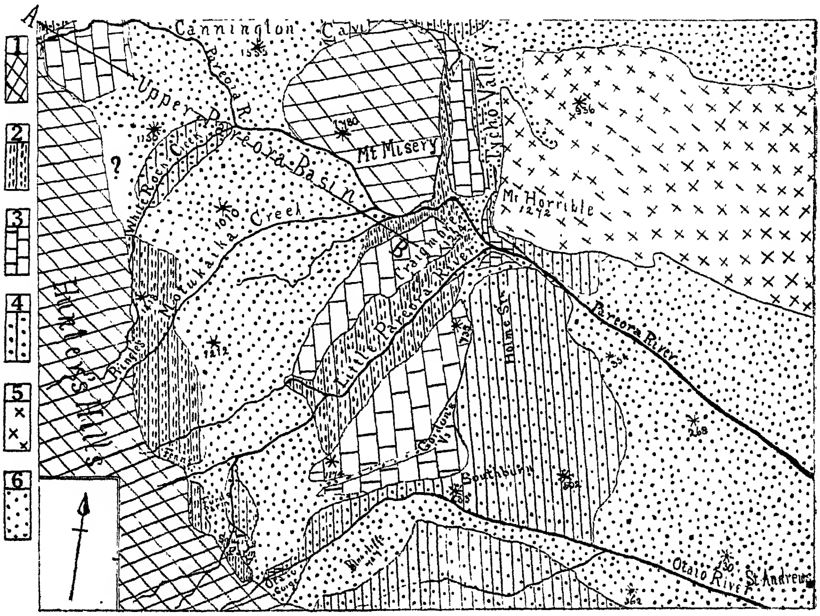


FIG. 1.—Stratigraphical map of the Pareora and neighbouring districts. (Scale, 4½ miles to 1 in., approx.) 1. Trias-Jura rocks, usually greywackes and mudstones. 2. Beds underlying the limestone, including quartz grits, sands and sandstones, crab-beds (greensands), and marls. 3. Limestone, including the white and flaky, "dark," and ordinary limestones. 4. The Pareora beds, including the blue clay and upper red sands. 5. Dolerite. 6. Gravels (old and new) and loess. The line AB gives the section across the Upper Pareora Basin.

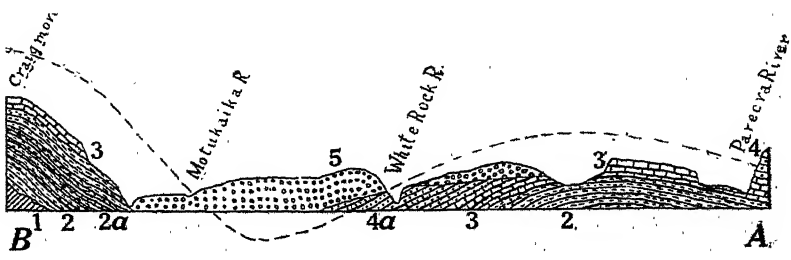


FIG. 2.—Section across Upper Pareora Basin (along the line AB in the map). Distance, 10½ miles; direction, E.S.E.-W.N.W. 1. Mesozoic rocks. 2. Grits and sands. 2a. Lower red sands with calcareous limestone. 3. Limestone. 4. Blue clay. 4a. Sandy clays (part of "upper red sands"). 5. Gravels.

The Coal Series.

Bordering the Hunter's Hills these beds are composed of grits and conglomerates alternating with coal-seams and followed by sands and sandstones. Farther east the lowest members of the series consist of pipeclays, followed by quartz grits, while the coal itself is represented by a narrow band of carbonaceous clay.

Usually the conglomerates are "puddingstone" conglomerates, consisting of quartz pebbles in an iron-stained matrix. The pebbles have a wide range in size, but ordinarily they are slightly larger than peas. They may also vary much in colour. They may be firmly cemented, forming a coarse sandstone, or they may be crumbly masses of quartz grains.

The pipeclay, which is of considerable thickness in some places, contains numerous concretions of iron-pyrites and limonite. Sometimes these concretions are long and narrow, containing a carbonized substance, which probably represents a piece of wood. The pipeclay has probably been formed by the kaolinization of the feldspar, which, with quartz, is the chief constituent of the greywacke and slates of Mesozoic age. These rocks form the backbone of the country, and the Tertiary series has been deposited on the flanks of the old land. By long-continued denudation these rocks gave up their constituents to form the deposits of the Tertiary series. The coal-beds thin out as they are followed eastward, and are replaced by the other members of the series.

There are only two important outcrops of coal in the Pareora district, and there is good reason to believe that they occupy different positions in the series. The coal at Otaio lies at the base of the Oamaru series, while the coal at White Rock seems to lie near the top of the Pareora series. The Otaio coal is a good brown coal when obtained from a dry part of the seam, but wet blocks crumble away and leave only a mass of "slack." The beds dip at 60°, so that it would be very difficult to follow the seam. It is also probable that the seam is not continuous over any large area, as it is not found at all in the excellent section of the coal series exposed at Craigmore. Like much of the New Zealand coal, it seems to have been formed in an estuary or bay. This theory is supported by the fact that the grits below the coal contain a small amount of carbonaceous matter, while the coal contains much grit, and the overlying clays again contain pieces of wood. The coal does not seem to have been formed by growth *in situ.*

The Lower Sands and Sandstones.

The grits and clays which alternate with the coal-seams are immediately followed by a succession of sands and sandstones. These vary in colour from grey and green to bright red. Usually the shells in the sands are in poor condition, but those which are found in the sandstones are well preserved. One noteworthy feature of these sands and sandstones is the quantity of carbonaceous matter found in them. In certain layers there are species of simple corals, which are characteristic of this horizon throughout South Canterbury and North Otago. The evidence of the fossils and of the lithological characters of the beds demonstrates that they were formed in comparatively shallow water.

The Crab-beds and Marls.

The crab-beds are dark-coloured marls, which grade upwards into grey marls. They are usually brown, but often they are so glauconitic as to deserve the name of "greensands." Their character is very uniform

throughout South Canterbury and North Otago, so that they are easily recognized. A few pectens and oysters are almost the only molluscs to be seen in the marls, but the numerous concretions which these contain enclose several species of molluscs, in addition to sharks' teeth and crabs. These lower marls are rather coarse, suggesting that they were formed not far from the old shore-line. Petrified wood and fossil amber are found in these beds as well as in the lower sands and sandstones. The distinction between these and the lower sands and sandstones is an artificial one, as the one set of beds grades into the other.

The overlying marls are almost unfossiliferous, probably because the sea was becoming too deep for the shell-fish that had existed in the earlier periods when the beds were laid down in comparatively shallow water. They are transition beds, which were formed before the deep-sea fauna could take possession of its new territory. The first of the new colonists were crinoids, and later came molluscs, such as *Atrina* and some pectens, together with echinoids and brachiopods. In the western part of the district these marls pass up into a chalky limestone; farther east the marls pass up directly into a dark limestone.

The Limestone.

This is an arenaceous limestone which passes upwards into clays and downwards into marls. Its colour varies from yellowish to greenish-white, owing to iron-stains and glauconitic sand. In some places near the old shore-line the surface of the limestone is dotted over with black spherules of ferric oxide, and sometimes small quartz pebbles may be found. It is possible that these pebbles were carried out from the shore by clumps of seaweed. The limestone is nearly always divided into hard and soft layers, which in weathering give the rock a characteristic fluted appearance. (See Plate XVI, fig. 1.) Followed eastward the rock becomes less arenaceous, and more compact and siliceous, especially in the upper layers. We find, too, that the thickness of the limestone has increased from 55 ft. to 100 ft. At the bottom of the ordinary stone there is a darker and more arenaceous bed which contains many brachiopods, in addition to large lamellibranchs, such as *Pecten huttoni* (Park), *Lima laevigata* Hutt., *Lima* (*Acesta*) *imitata* Sut. Sharks' teeth are common in this layer, but only a few are scattered through the upper part of the limestone. Sometimes the lamellibranchs are so numerous as to define a joint-plane; thus a fallen block may sometimes show hundreds of shells lying in the one plane.

Beneath this dark layer there is sometimes a fine-grained chalky limestone in which there are no traces of fossils. The whole of the main limestone is glauconitic, but this character is best seen in the lower (dark) band. Not only is the limestone thicker in all the areas remote from the old coastline, but the change from limestone to marl is much more definite. There are numerous caves, which sometimes contain bones of extinct birds, such as *Harpagornis*, *Cnemiornis*, and *Dinornis*. A noteworthy feature of the weathering of the limestone is the tendency of solution to form deep, well-like shafts. In one place I noted as many as thirteen within an area of less than 20 acres. (See Plate XVI, fig. 2.)

The uppermost layer of limestone, passing into the blue clay, when examined microscopically is seen to be of very even texture, with a base of some argillaceous substance. *Globigerina* tests, and round bodies that are probably the detached chambers of *Globigerina*, are scattered all through the rock. These are sometimes replaced by an iron compound.

Small rounded grains of quartz are very common, and there are in addition plates of biotite and muscovite, and grains of glauconite and magnetite.

Marshall (1916) has described a specimen of the Otaio limestone as follows: "A fine-grained type, with many minute quartz grains and a good deal of glauconite. Mainly *Globigerina*, but one specimen of *Amphistegina*."

The Pareora Beds.

These consist of bluish-green clays, which pass gradually up into fine reddish-brown sands and sandstones. Where fully exposed these beds show a total thickness of about 700 ft. Throughout South Canterbury and much of North Otago they are extremely constant in such characters as the bluish-green colour of the clays and the reddish colour of the sands. Again, the lower parts of the red sands always contain concretions, while the middle parts always have many layers of calcareous sandstones crowded with molluscs. Finally, the highest part of the red-coloured beds is practically devoid of fossils, suggesting that the water was so strongly charged with iron as to kill the shell-fish. The change from a blue clay to an iron-stained sand supports the inference that these were the closing members of the series. Thus the great cycle of deposition was completed: conglomerate, grits and coal, sands and sandstones, marl, glauconitic limestone, ordinary limestone, blue clay, red sands. At the Lower Waipara, in North Canterbury, Speight (1914) has shown that the uppermost marine beds are interstratified with gravels.

Detailed Descriptions by Localities.

Otaio Gorge.

Here the whole sequence from the quartz grits to the limestone is exposed in a section where the beds are seen dipping E.N.E. at 60°. The field relations of the beds are shown in fig. 3. The grits contain at least

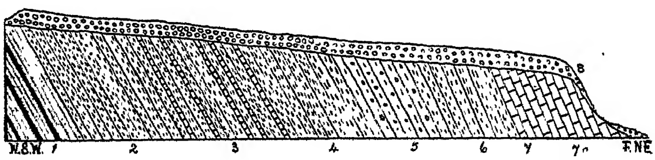


Fig. 3.—Section along Otaio River, near the Gorge. Distance, slightly over 200 yards; direction, W.S.W.–E.N.E.; dip, 60°. 1. Sands and grits with coal. 2. Lowest fossiliferous sands. 3. Sands with calcareous sandstone. 4. Red sands. 5. Crab-beds with concretions (greensands). 6. Grey marls. 7. White flaggy limestone and dark limestone. 7a. Ordinary limestone. 8. Gravels.

eight coal-seams, of an average thickness of 2 ft. The first of the marine sandstones occur as layers in sandy clays. These clays contain few fossils, but the sandstone is crowded with shells of *Cardium waitakiense* Sut. and *Venericardia zelandica* (Desh.) var.

In the sandy clays there are layers of corals, chiefly *Balanophyllia hectori* T.-W. The overlying crab-beds have even fewer fossils than usual, but they are easily recognized by their colour and their numerous concretions, while an occasional crab may be found. Besides the latter, I collected *Pecten huttoni* (Park) and *Panope* sp. The marls, as usual, are practically devoid of fossils. The lower sands and sandstones overlying yielded a rich molluscan fauna, tabulated in column 1 of the table on page 259, and in

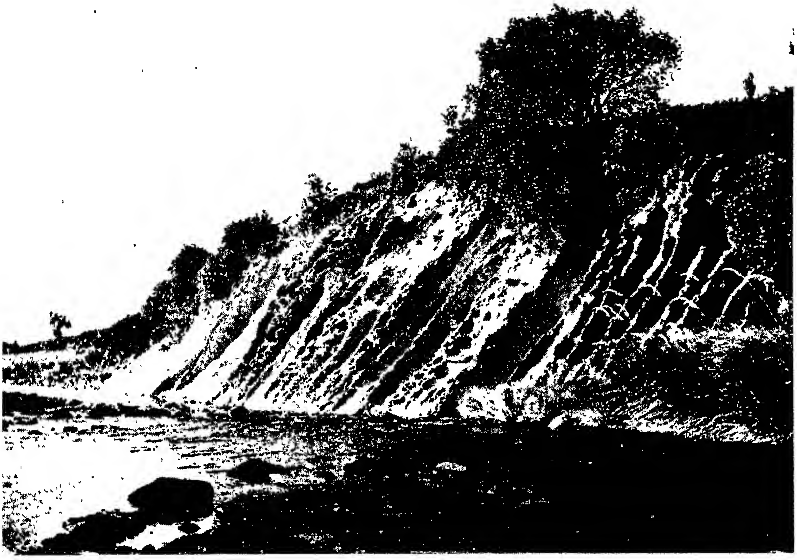


Fig. 1.—View of the fluted limestone at Otaio Gorge. Almost the whole thickness of the limestone is shown in the photograph.

Fig. 2.—Solution-pits in the limestone on Holme Station, seen from the Gordon's Valley – Little River Road.

Face p. 250.]

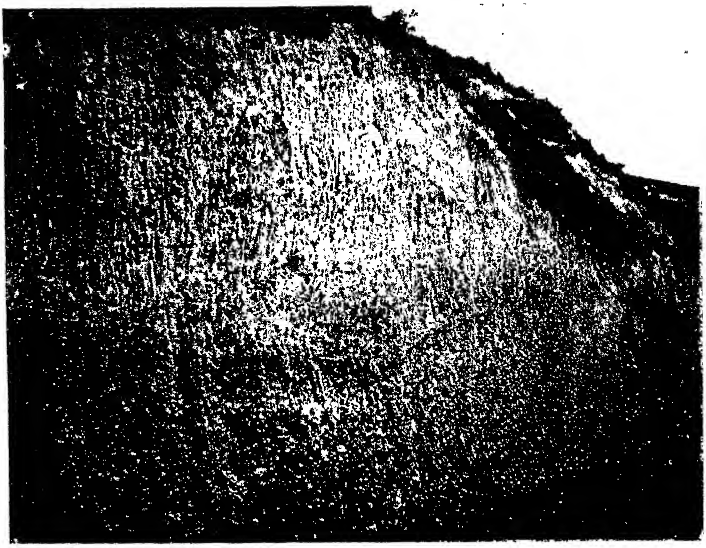


FIG. 1.—Road-cutting on Squire's Farm. The columnar structure of the loess is well seen. The lower part is a residual clay, passing into coarse gravels which lie on the limestone.

FIG. 2.—The upper part of Little River Valley, viewed from Squire's Farm. The rock in the foreground is the uppermost part of the limestone, with soft layers. In the middle distance, on the left, the white flaky limestone is seen passing up into the dark and ordinary limestones, which in turn pass up into the blue clay. The wide river-terraces are well shown here.

addition some fish-remains, echinoderm-spines, and the following corals: *Flabellum sphenodeum* T.-W., *Balanophyllia hectori* T.-W., and *Sphenotrochus huttonianus* T.-W.

The chalky limestone has no fossils except Foraminifera and other microscopic forms, while the dark limestone and the ordinary limestone have only a few brachiopods—viz., *Pachymagas ellipticus* Thomson and *Aetheia gualteri* (Morris).

Bluecliffs.

Following the Otaio for four miles, we come to a long line of cliffs of blue clay, whence the district takes its name. These beds can be traced all the way from the Otaio Gorge, and are certainly resting on the limestone, though no actual junction is shown. The relation of the two beds, however, is clearly seen at Squire's, Gordon's Valley, Cannington, and Mount Horrible.

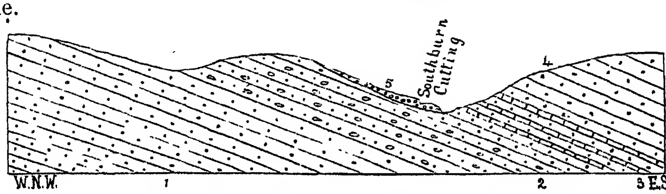


FIG. 4.—Section along Otaio River at Bluecliffs. Distance, about ¾ mile; direction, W.N.W.–E.S.E.; dip, 20°. 1. Blue clays. 2. Lower part of the red sands, with concretions. 3. Middle part of the red sands, with calcareous sandstone. 4. Upper part of the red sands. 5. Gravels.

The blue clays seem to reach their maximum thickness here, for they are at least 350 ft. thick (see fig. 4). The fossils occur very sparingly, but the great exposure of strata enables one to make a good collection. These bluish-green clays yield the molluscs tabulated in column 5 of the table of fossil mollusca, and in addition small nautiloids, annelids, scutes, and *Pachymagas parki* (Hutt.), *Trochocyathus mantelli* T.-W., *Flabellum circulare* T.-W., and *F. laticostatum* T.-W.

Southburn Cutting.

At the Southburn Cutting, at the end of the Bluecliff section, the blue clays are seen passing into red sands, with concretions. Higher up in these sands there are bands of calcareous sandstone. These beds are not richly fossiliferous, like the corresponding beds elsewhere, and in the highest part of the series there are no fossils at all.

This exposure shows the sands to be very thick, probably 400 ft. at least, and I think that the uppermost part of them is the youngest marine formation in South Canterbury.

From the sands, concretions, and sandstone layers I collected the molluscs tabulated in column 9 of the table of fossil mollusca, and in addition the brachiopod *Pachymagas parki* (Hutt.).

Gordon's Valley.

This valley begins near the western end of the exposure of blue clays at Bluecliffs, and passes first of all through the limestone, and then through the blue clays and red sands. The stratigraphy is clear, and shows the relations of the Pareora beds to the limestones. The upper part of the limestone at the head of the valley is more siliceous than usual, and has a fluted appearance due to the alternation of hard and soft layers. There are practically no fossils in the upper part, but in the lower part there are echinoids and crinoids, with a few brachiopods.

Just below Mr. P. Elworthy's homestead the blue clays are seen overlying the limestone and passing up into the red sands and sandstones. If the road from Gordon's Valley to Little River Valley be followed, first the blue clay and then the limestone will be passed over. In the valley leading down into Little River Valley the limestone is well exposed in cliffs 100 ft. high. The lower parts contain many brachiopods, and a few other fossils, such as *Epitonium browni* (Zitt.), but the upper parts are very siliceous, and in places there are flint nodules which stand out like pegs from the weathered surfaces.

The red sands have their usual characteristics: thus the lower part has concretions scattered through it, and then come alternating layers of hard sandstones and soft shelly bands. Above this there are the true red sands, with layers of shells, such as species of *Venericardia*, *Polinices*, *Turritella*, *Limopsis*, and *Dentalium*. These beds may be traced down to the back of the homestead at Holme Station.

On the road over into Little River Valley, the solution-pits in the limestone can be seen. (Plate XVI, fig. 2.)

From the limestone at this locality I collected *Pericosmus compressus* McCoy and *Pentacrinus stellatus* Hutt. The red sands yielded the molluscs tabulated in column 10 of the table of fossil mollusca.

Squire's Farm. (Plate XVII, figs. 1 and 2.)

This locality is very important for showing the relationship between the Pareora beds and the underlying beds. Every member of Marshall's "Oamaru system" as developed in the Pareora district is exposed in the banks of the Little Pareora River where it flows through this farm. The grits of the coal series are very thick here, but the coal itself is not shown in any exposure. Puddingstone conglomerates are interbedded with the grits. The lowest fossiliferous beds are found near the top of the landslip facing the road to Otaio Gorge. They are strongly impregnated with iron oxides, which have replaced the fossils, so that only casts can be obtained. The harder bands stand out as reefs and ridges on the hillside. The fossils obtained were *Dosinia lambata* (Gould), *Pecten huttoni* (Park), *Chione* sp., and *Polinices* sp.

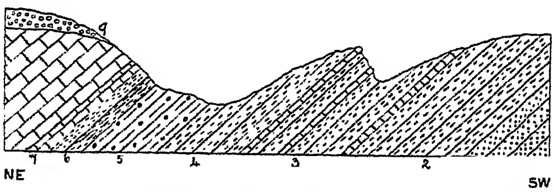


FIG. 5.—Section along right bank of Little River, in Squire's Farm. Distance, 300 yards; direction, N.E.-S.W.; dip, 40°. 1. Grits and sands of coal series. 2. Lowest fossiliferous sands. 3. Lower red sands, with calcareous sandstones. 4. Red sands. 5. Crab-beds (seen in the bed of the river). 6. Grey marls (seen in the bed of the river). 7. White flaky limestone and dark limestone. 8. Limestone, current-bedded. 9. Gravels.

The crab-beds and marls are not exposed on the hillside, but they appear in the bed of the river near the sharp turn in the river. They may be described as typical greensands with concretions, but usually these beds are rather too brown and marly to be called "greensands." They yielded *Panope worthingtoni* Hutt. and *Turritella* sp.

The next bed exposed consists of a white limestone, which breaks into small cubes and flakes similar to those found in the Amuri limestone at Weka Pass. This limestone is seen in the bed of the river for more than a quarter of a mile, and is well exposed in a section on the right bank. Its greatest thickness in an exposure is 14 ft., but it may really be as much as 20 ft. Near the top its uniform texture changes, and the rock assumes a speckled appearance, due to the presence of tubes or pipes filled with grey limestone, similar to that found in the overlying stone. There is no erosion surface or other sign of unconformity, so that the change in the character of the rock was due to a change in the conditions of deposit. Some of the tubes appear to be worm-borings, but most of them are too large for such an origin.

The dark limestone is 4 ft. 6 in. thick in one section, but its thickness varies. In places it is indistinguishable in colour from the ordinary limestone, but it is always softer and more arenaceous, and it contains more fossils. In the first exposure seen on Squire's Farm this limestone is crowded with brachiopods, and sharks' teeth are common in "pockets."

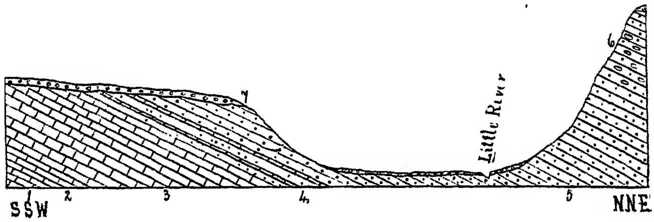


FIG. 6.—Section across Little River, in Squire's Farm. Distance, about 180 yards; direction, S.S.W. - N.N.E.; dip, 25°. 1. White flaky limestone. 2. Dark limestone. 3. Limestone. 4. Limestone with soft layers, passing into blue clay. 5. Blue clay. 6. Lowest horizon of upper red sands, with large concretions. 7. Gravels.

The uppermost layer, about 1 ft. thick, contains frequent specimens of *Lima* (*Plagiostoma*) *laevigata* Hutt. and *Pecten huttoni* (Park). In many of the fossils, the carbonate of lime is replaced, wholly or partly, by iron oxides. The complete list of fossils collected is as follows: *Epitonium lyratum* (Zitt.), *E. browni* (Zitt.), *Lima laevigata* Hutt., *Pecten huttoni* (Park), *P. scandula* Hutt. (?), *Echinus* sp., *Eupatagus greyi* Tate, *E. tuberculatus* Zitt., *Balanus* sp., *Aetheia gualteri* (Morris), *Pachymagas ellipticus* Thomson, *Rhizothyris rhizoida* (Hutt.), *Liothyrella landonensis* Thomson, *Lamna huttoni* Davis, *L. incurva* Davis, *Oxyrhina grandis* Davis, and *Kekenodon onomata* Hector (?).

The ordinary limestone affords a fine example of current-bedding, and this fact, taken in conjunction with the arenaceous nature of the rock and the number of quartz grains seen in a microscopic slide, shows that the deposit was not formed in deep water. The fossils obtained from the ordinary limestone were: *Epitonium lyratum* (Zitt.), *E. browni* (Zitt.), *Lima laevigata* Hutt., *L. paleata* Hutt. (?), *Pecten huttoni* (Park), *P. williamsoni* Zitt., *Atrina zelandica* Gray, *Eupatagus greyi* Tate, *Pericosmus compressus* McCoy, *Pentacrinus stellatus* Hutt., *Cidaris* spines, *Retepora* (?), *Graphularia* sp., *Aetheia gualteri* (Morris), *Liothyrella landonensis* Thomson, *Terebratulina suessi* Hutt., *Rhizothyris rhizoida* (Hutt.), *Pachymagas huttoni* Thomson, *P. parki* (Hutt.), and *Hemithyris nigricans* (Sow.).

Farther down the river the white flaggy limestone appears in the left bank, but most of the dark limestone is covered with shingle. The ordinary limestone is well shown, but it has even fewer fossils than usual. The section is perfectly clear, and shows the limestone passing very gradually into the blue clay. The transition is marked by alternations of hard and of soft layers. There is a small reversed fault here, with an upthrust of 2 ft. and a hade of 5°. In the first interbedded soft band a small nautiloid, *Pecten huttoni* (Park), *Pachymagas parki* (Hutt.), and species of *Flabellum* are almost the only fossils. In the first horizon of the blue clay proper the commonest fossils are species of *Flabellum* and *Trochocyathus*, and *Limopsis aurita* Brocchi. In the creek-bed many small species are found, such as *Alectrion socialis* (Hutt.) and *Corbula canaliculata* Hutt. At the foot of the landslip the ordinary fossils of the blue clay appear; of these *Pecten zitteli* Hutt. is more common than usual. A list of the molluscs obtained is given in column 6 of the table, and in addition the following were found: a small nautiloid, *Pachymagas parki* (Hutt.), *Flabellum circulare* T.-W., *Trochocyathus mantelli* T.-W., a scute (?), and whale-bones.

Near the top of the slip, in the little patch of bush, the blue clays are seen passing into red sands with concretions. These beds are best seen on the right bank a little below the slip, and the middle and upper horizons are seen half a mile down the river on the left bank. The following fossils were collected: *Turritella semiconcava* Sut., *Polinices ovatus* (Hutt.), *P. gibbosus* (Hutt.), *Siphonalia costata* (Hutt.), *Ancilla hebera* (Hutt.), *Surcula fusiformis* (Hutt.), *Pecten huttoni* (Park), *Venericardia pseutes* Sut., *Nucula sagittata* Sut., and *Chione meridionalis* (Sow.). Owing to the smallness of this collection, it so happens that no Recent species were found here, but the character of the beds, the stratigraphy, and the nature of these fossils all show that these are the ordinary upper red sands.

The loess is well shown in the saddle between the Otaio Gorge and Little River, and in a cutting made for a new road through Squire's Farm. (See Plate XVII, fig. 1.)

White Rock.

Here only the upper beds of the series are exposed, but their rich fauna has made them very important. The beds show the effects of gentle folding, for the dip alters gradually as we go westwards. There is an interesting occurrence of a lignite in these beds. It does not belong to the coal series, but seems to be almost contemporaneous with the marine fauna found in the ordinary layers. The fossils are found in wonderful profusion in a few narrow layers, but they seem to follow exactly the same order as at Sutherland's. Thus the struthiolarias are confined almost wholly to the upper layer, while the flat lamellibranchs, such as *Zenatia acinaces* (Q. & G.), *Chione speighti* Sut., &c., are confined to the lower. The molluscs collected are given in column 11 of the table, and in addition *Myliobates* sp. and *Arachnoides placenta* were obtained.

Mount Horrible (Pareora River).

At the foot of Mount Horrible the river has exposed the limestone, the blue clay, and the red sands. The limestone clearly underlies the blue clay, which in turn passes up gradually into red sands. The limestone at the kiln is very siliceous, with flint nodules. The blue clays are well exposed in the slip at the Fishermen's Huts, and can be followed down the left bank of the river for about one mile and a half. The red sands are found at the level of the water-race above the slip, and in a gully which runs up

towards the dolerite. The highest exposure of the red sands occurs about 20 ft. below the dolerite, but, as at Sutherland's and Southburn Cutting, the uppermost beds are devoid of fossils. The intermediate parts of the red sands — namely, those with concretions and layers of shelly sandstones—are not well exposed on the left bank, but they appear on the other side of the valley, in Holme Station.

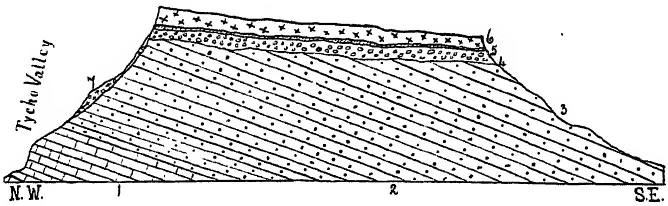


FIG. 7.—Section across south-west corner of Mount Horrible. Distance, about 1¼ miles; direction, N.W. - S.E.; dip, 15°. 1. Limestone. 2. Blue clays. 3. Red sands. 4. Gravel. 5. Ash. 6. Dolerite. 7. Talus.

From the blue clay I collected the molluscs tabulated in column 7 of the table, and in addition *Pachymagas parki* (Hutt.), *Flabellum circulare* T.-W., *F. laticostatum* T.-W., *Trochocyathus mantelli* T.-W., and annelid-tubes. From the upper red sands I obtained *Ampullina suturalis* (Hutt.), *Hemiconus traílli* (Hutt.), and *Chione* sp.

Cave and Sutherland's.

The beds exposed in these two localities are—the lower sands and sandstones, the crab-beds and marls, the limestone, the blue clay, and the upper red sands. The sequence is exactly the same as at Squire's Farm, Mount Horrible, and Cannington. The lower red sands are seen in the right bank of the Tengawai, a quarter of a mile above the railway-station. They contain only a few fossils, as they are the uppermost horizon; the lower horizons, with corals, have not yet been cut into by the river. In one exposure these sands show current-bedding.

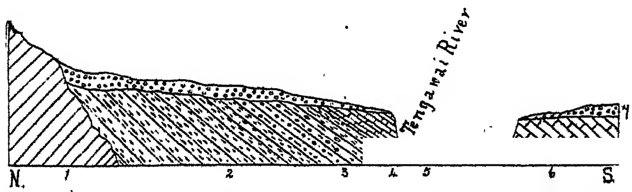


FIG. 8.—Section across Tengawai River, at Cave. Distance, ¼ mile; direction, N.-S.; dip, 35°. 1. Greywacke. 2. Sands. 3. Crab-beds (greensands) with concretions. 4. Marls. 5. Dark arenaceous limestone. 6. Ordinary limestone. 7. Gravels.

The crab-beds and marls are well exposed on the left bank, above Cave. They have their usual lithological character, but the concretions contain molluscs, chiefly lamellibranchs, instead of crabs. On the left bank the marls are seen to be overlain by a dark arenaceous limestone, which is thicker than usual. From the surface of contact I collected *Lima imitata* Sut. and various pectens. The limestone is also seen in the bed of the river and in the right bank at the bridge. Just below the bridge I collected a number of fossils from the limestone. Fine exposures are found

on the left bank, where the limestone forms cliffs over 80 ft. high. Still farther down there is an exposure of the limestone close in against the greywacke. This would seem to have been faulted down, but the throw of the fault could not have been very great. In the quarry there are two faults, with slickensides, and much of the limestone appears to have been crushed and deformed by pressure.

The blue clay is seen in the river-bed at the new bridge leading to Totara Valley, and in the terrace south of the railway-line, where the road passes over to Tycho Flat. Half a mile farther down the red sands are well exposed beside the railway. The upper portions of the red sands are exposed all along the valley at the back of the school, but the fossiliferous horizons are not well exposed there. Near the railway-line the first beds are brown sands, with calcareous sandstone in layers. These sands change to very red sands, with practically no fossils. Again the beds are brown, with no fossils. The first layer of sandstone in this horizon is crowded with species of *Psammobia* and other flat shells, and *Polinices* and *Natica.* The top layer has many specimens of *Turritella cavershamensis* Harris, and species of *Struthiolaria*, *Glycymeris*, and *Dosinia.* There are also two soft shelly layers crowded with *Turritella cavershamensis* Harris, as at White Rock. This is the horizon of *Latirus brevirostris* (Hutt.) and *Hemiconus trailli* (Hutt.). Except for the difference in colour, the beds are exactly similar to those of White Rock.

From the lower red sands (Waihao beds) I obtained the following: *Turritella cavershamensis* Harris, *T. symmetrica* Hutt., *Struthiolaria* sp., *Polinices gibbosus* (Hutt.), *Ancilla hebera* (Hutt.), *Cardium waitakiense* Sut., and *Glycymeris laticostata* (Q. & G.).

The crab-beds at Cave yielded *Cucullaea alta* Sow., *Chione meridionalis* (Sow.), and *Limopsis aurita* (Brocchi).

I collected from the limestone at Cave *Ampullina* sp., *Pecten williamsoni* Zitt., *P. burnetti* Zitt., *P. huttoni* (Park), *Lima* (*Acesta*) *imitata* Sut., *Ostrea* sp., *Pachymagas parki* (Hutt.), *P. huttoni* Thomson, *Liothyrella gravida* (Suess), *Rhizothyris rhizoida* (Hutt.), *Terebratulina suessi* Hutt., *Balanus* sp., *Pentacrinus stellatus* Hutt., *Pericosmus compressus* McCoy, and *Eupatagus tuberculatus* Zitt.

The upper red sands at Sutherland's yielded the sixty-four species of molluscs tabulated in column 12 of the table.

Little River and the South-west End of Craigmore.

On the banks of the Little River and its chief tributary there are fine exposures of all the beds from the quartz grits up to the limestone. The grits and sands of the coal series are typically developed above the junction of the two streams, but the coal is represented by a narrow band of carbonaceous clay. The lowest Tertiary bed consists of pipeclay which was laid down on the eroded surface of the Mesozoic rocks. The grits are snow-white in most of this locality.

The lower sands and sandstones are seen lying on top of the grits, but they are not so fossiliferous as at Otaio Gorge. Below the junction these beds are found in the river-bed, and consist of sands with bands of concretionary sandstone and layers of soft crumbly shells. The commonest fossils in this exposure are *Venericardia zelandica* (Desh.) var. and *Turritella symmetrica* Hutt., and a few specimens of *Ostrea gudexi* Sut. may be found. The lower sands and sandstones are exposed all along the left bank until the end of the valley is reached, and they appear in the cuttings on the road that passes above the Pareora dam.

The crab-beds are well seen half-way up the hill on the left bank of the tributary, and have their usual character. The concretions contain a few crabs, while specimens of *Cucullaea alta* Sow., partly replaced by iron compounds, are found scattered through the beds. The crab-beds may be followed all along the Little River Valley, first on the left bank, then in the bed of the river, and then along the right bank until the lime-kiln is approached. One mile above the kiln the crab-beds are seen passing up into marls of a greenish-grey colour. These are the "grey marls" described by McKay. The same beds are seen in the left bank, above the bridge.

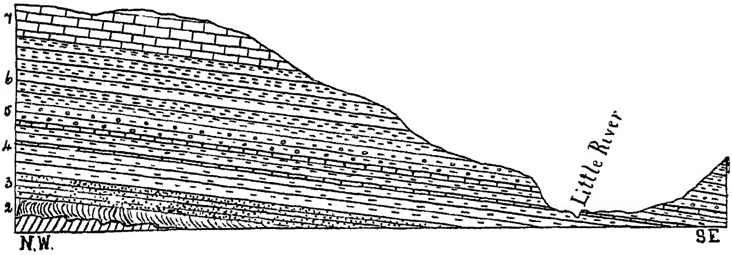


FIG. 9.—Section along left bank of main tributary of Little River, above the junction Distance, ¾ mile; direction, N.W.–S.E.; dip, 10°. 1. Trias-Jura. 2. Pipeclay. 3. White quartz grits, with carbonaceous shales. 4. Sands with calcareous sandstone. 5. Crab-beds (greensands) with small concretions. 6. Marls, grey at the top. 7. Limestone.

The limestone forms the crown of the Craigmore Block, and appears on Holme Station at a lower level. It exhibits folding at both ends of Craigmore, where an anticlinal structure appears. At the north end, in a section S.S.W.–N.N.E., the dip is 10° to the south-south-west; and still farther on, in a section W.–E., the dip is 40° to the west; while in a section at the crest, running west and east, the dip is 0°. The eastern limb has been almost completely shorn away by the action of Little River, but the limestone on Holme Station and in Mount Horrible enables us to reconstruct the anticline. At the south-west end of Craigmore the structure is not quite so clear, chiefly because the anticline dies away in the next mile or two, and is followed by an unsymmetrical syncline in the direction of Squire's Farm.

There is a small, superficial fresh-water deposit on the left bank of Little River, about two miles above the bridge, and from it I collected specimens of a fresh-water gasteropod which Mr. Suter says is new.

The lower red sands and sandstones yielded *Polinices suturalis* (Hutt.), *Typhis maccoyi* T.-W., *Volutospina* sp., *Crassatellites obesus* (A. Ad.), and *Astarte* ? sp.

From the crab-beds on the left bank I collected *Struthiolaria tuberculata* Hutt., *Ancilla hebera* (Hutt.), *Surcula fusiformis* (Hutt.), *Cucullaea alta* Sow., *C. attenuata* Hutt., *Atrina zelandica* (Gray), *Ostrea* sp., and *Macrocallista assimilis* (Hutt.).

From the upper crab-beds, one mile above the lime-kiln, I obtained *Turritella symmetrica* Hutt., *Polinices gibbosus* (Hutt.), *Ancilla* sp. nov., *Dentalium solidum* Hutt., *Crassatellites obesus* (A. Ad.), *Ostrea nelsoniana* Zitt., *Gryphaea tarda* Hutt., *Pecten* (*Chlamys*) *williamsoni* Zitt., *P. hilli* Hutt., *P. huttoni* (Park), *P. delicatulus* Hutt., *Pecten* sp. nov. between *triphooki* and *zelandiae*, *Macrocallista assimilis* (Hutt.), *Teredo directa* Hutt., *Holaster* sp., and *Cidaris* spines.

Craigmore.

At the north end of Craigmore there is an exposure of the whole series of Tertiaries from the quartz grits to the limestone. The grits are resting on the Mesozoic rocks, which have been cut down to a depth of about 300 ft. by the Pareora River. The marine sandstones, as usual, contain layers of *Cardium waitakiense* Sut. and *Venericardia zelandica* (Desh.) var. The limestone which forms the crest of Craigmore occupies the summit of an anticline, which pitches west to form the Upper Pareora basin. From the limestone I collected *Epitonium lyratum* (Zitt.), *E. browni* (Zitt.), *Pecten huttoni* (Park), *Lima laevigata* Hutt., *Aetheia gualteri* (Morris), *Terebratulina suessi* Hutt., *Rhizothyris rhizoida* (Hutt.), *Liothyrella landonensis* Thomson, *Pachymagas parki* (Hutt.), *Flabellum radians* T.-W., *F. circulare* T.-W., *Retepora* sp., *Graphularia* sp., *Eupatagus tuberculatus* Zitt., *E. greyi* Hutt., *Pericosmus lyoni* Tate, *P. compressus* McCoy, *Pentacrinus stellatus* Hutt., *Oxyrhina grandis* Davis, *Lamna huttoni* Davis, *L. incurva* Davis, and *Kekenodon* (?).

Tycho Valley.

Along the right bank of this valley there is a steep limestone slope, and in one place this is overlain by a deposit of blue clay, which is the only evidence that all this limestone was once covered by the blue clay. From the clay I collected *Chione meridionalis* (Sow.), *Crassatellites obesus* (A. Ad.), and *Limopsis aurita* (Brocchi).

Holme Station.

In this locality the upper red sands and sandstones are seen dipping south-east at 15°. The lowest beds have few fossils, but the upper beds contain concretions and hard calcareous layers, as at Southburn Cutting and Gordon's Valley. They contain a rich fauna, and it is noteworthy that this is the exposure from which the first "Pareora" fossils were collected. I collected here the sixty-nine species of molluscs tabulated in column 13 of the table.

Cannington.

The only Tertiary beds exposed here are the limestone, the blue clay, and the upper red sands. The section is noteworthy, as the beds dip into instead of away from the Trias-Jura rocks. The limestone is well seen on the right bank, where it dips in one section to the north-north-east at 40°, and in another section to the north-north-west at 10°.

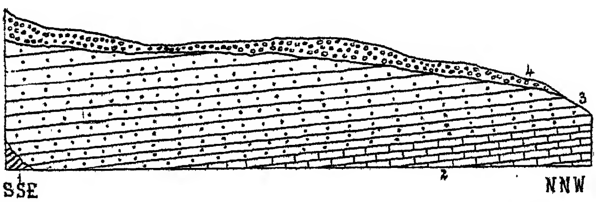


FIG. 10.—Section along left bank of Pareora River, near the upper gorge (Cannington). Distance, about ¾ mile; direction, S.S.E. – N.N.W.; dip, 10°. 1. Greywacke. 2. Limestone. 3. Blue clay. 4. Gravel. (The westerly part of the section is obscured by gravels.)

On the left bank the limestone is followed conformably by blue clays, as at Squire's Farm, but heavy deposits of gravel have obscured the upper

parts of the section. About a mile farther down, however, the red sands are seen in the cuttings made for the road that passes over the steep hill on the left bank.

The limestone yielded *Epitonium lyratum* (Zitt.), *E. browni* (Zitt.), *Pachymagas* sp., echinoderm spines and plates, and *Pentacrinus stellatus* Hutt.

From the blue clay lying only a few feet above the limestone I collected *Turritella concava* Hutt., *Crepidula gregaria* Sow., *Polinices* sp., *Surcula fusiformis* (Hutt.), *Dentalium mantelli* Zitt., *D. ecostatum* T. W. Kirk, *Malletia australis* (Q. & G.), *Pecten huttoni* (Park), *P. zitteli* Hutt., *Chione meridionalis* (Sow.), *Chione chiloensis truncata* Sut., *Limopsis aurita* (Brocchi), *Corbula canaliculata* Hutt., *Cochlodesma angasi* (C. & F.) (?), and *Pachymagas parki* (Hutt.).

Ford's, Fenn's, and Pringle's.

If we follow the road along the foothills, from Squire's Farm to White Rock, we find that almost the only Tertiary beds exposed are the grits of the coal series. Between Squire's Farm and the first tributary of Little River, however, a marine sandstone is found in one of the road-cuttings, and farther on there is a small outcrop of limestone on the left of the road. This limestone lies close in against the greywacke, and its position is hard to account for, unless it has been faulted down.

From the sandstone I collected the following fossils: *Turritella symmetrica* Hutt., *Ancilla australis* (Sow.), *Psammobia lineolata* Gray, *P. zelandica* Desh., *Venericardia pseutes* Sut., *V. zelandica* (Desh.) var., *Macrocallista assimilis* (Hutt.), *Modiolus dolichus* Sut., and *Cardium waitakiense* Sut.

TABLE OF FOSSIL MOLLUSCA.

(Recent species are marked with an asterisk before the name; complete faunas of formations throughout the district are followed by a double rule.)

Column 1. Lower sands and sandstones, Otaio Gorge.
Column 2. Complete fauna of lower sands and sandstones (Waihao beds) throughout the district.
Column 3. Complete fauna of crab-beds and marls throughout the district.
Column 4. Complete fauna of the limestones throughout the district.
Column 5. Bluish-green clays, Bluecliffs, Otaio River.
Column 6. Blue clays, Squire's Farm.
Column 7. Blue clays, Pareora River, foot of Mount Horrible.
Column 8. Complete fauna of blue clays throughout the district.
Column 9. Upper red sands with concretions, Southburn Cutting.
Column 10. Upper red sands, Gordon's Valley.
Column 11. Upper beds of the series, White Rock River.
Column 12. Upper red sands, Sutherland's.
Column 13. Upper red sands, Holme Station.
Column 14. Complete fauna of upper red sands throughout the district.
Column 15. Complete fauna of the Pareora series (columns 8 and 14).

—		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Alectrion socialis (Hutt.)	..	..	..	..	..	×	×	×	×	×	×	×	×	..	×	×
Ampullina suturalis (Hutt.)	..	×	..	..	..	×	×	×	×	×	..	×	×	×	×	×
Amusium zitteli (Hutt.)	..	..	..	..	..	..	×	..	×	..	..	..	..	..	..	×
**Ancilla australis* (Sow.)	..	..	..	..	..	..	×	×	×	..	×	×	×	..	×	×
* " *depressa* (Sow.)	..	..	..	..	..	..	×	..	×	..	..	×	..	..	×	×
" *hebera* (Hutt.)	..	*Cf.*	×	×	..	×	..	×	×	..	×	×	×	×	×	×
* " *novae-zelandiae* (Sow.)	..	..	..	..	..	×	×	..	×	×	..	..	..	..	×	×
" *papillata* (Tate)	..	..	..	..	..	×	..	..	×	..	..	..	×	×	×	×
" *waikopiroensis* Sut.	..	..	..	..	..	..	..	×	×	..	..	..	..	..	..	×

—	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
**Anomia huttoni* Sut.	..	..	..	..	..	..	..	..	..	..	..	..	×	×	×
,, *trigonopsis* Hutt. ..	..	..	..	..	..	..	..	..	..	..	..	..	×	×	×
* ,, *undata* Hutt.	..	..	..	..	..	..	..	..	..	..	×	..	×	×	×
* ,, *walteri* Hect.	..	..	..	..	..	..	..	..	..	..	×	×	×	×	×
Architectonica cf. *ngaparaensis* Sut.	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..
Astarte australis Hutt. (?) ..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..
**Atrina zelandica* (Gray) ..	..	..	×	×	×	×	..	×	..	..	..	..	..	..	×
Bathytoma haasti (Hutt.) ..	..	..	..	..	×	×	×	×	..	..	..	×	..	×	×
,, *sulcata* (Hutt.) ..	×	×	..	..	×	×	..	×	..	..	×	×	×	×	×
,, ,, *excavata* Sut...	..	..	..	..	..	..	×	×	..	..	×	..	..	×	×
Borsonia cincta (Hutt.) ..	..	..	..	..	..	..	×	×	..	..	×	..	..	×	×
Bulla sp. (?)	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..
**Calyptraea alta* (Hutt.) ..	..	..	..	..	..	..	..	..	..	..	..	..	×	×	×
* ,, *maculata* (Q. & G.) ..	×	×	..	..	×	×	×	×	×	..	×	×	×	×	×
* ,, ,, *inflata* (Hutt.)	..	..	..	..	×	×	..	×	..	..	..	..	×	×	×
Cardium greyi Hutt.	..	..	..	..	..	..	..	..	..	..	×	×	..	×	×
,, *waitakiense* Sut. ..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..
Cerithium hectori Harris ..	..	..	..	..	..	..	..	..	..	..	×	..	..	×	×
Chione acuminata Hutt. ..	..	..	..	..	..	..	..	..	..	..	..	×	..	×	×
,, *chiloensis truncata* Sut. ..	..	..	..	..	×	×	×	×	×	..	..	..	..	×	×
,, *meridionalis* (Sow.) ..	×	×	×	..	×	..	..	×	×	..	..	×	×	×	×
,, *speighti* Sut.	..	..	..	..	..	..	..	..	×	..	×	×	×	×	×
**Cochlodesma angasi* (C. & F.) (?)	..	..	..	..	..	..	..	..	..	..	..	..	×	×	×
Cominella carinata (Hutt.) ..	..	..	..	..	..	..	..	..	..	..	..	×	..	×	×
,, *pulchra* Sut. ..	..	..	..	..	×	..	..	×	..	..	..	..	..	..	×
Corbula canaliculata Hutt. ..	×	×	..	..	×	×	×	×	×	..	×	..	×	×	×
Crassatellites amplus (Zitt.) ..	..	..	..	..	..	..	?	?	..	..	×	..	..	×	×
* ,, *obesus* (A. Ad.) ..	×	×	×	..	×	×	×	×	×	×	..	×	×	×	×
**Crepidula costata* (Sow.) ..	..	..	..	..	..	..	..	..	×	..	..	×	..	×	×
,, *gregaria* Sow. ..	..	..	..	..	..	..	..	×	..	..	×	×	×	×	×
* ,, *monoxyla* (Less.) ..	..	..	..	..	..	×	..	×	..	..	×	×	×	×	×
,, *striata* (Hutt.) ..	..	..	..	..	..	..	..	..	..	..	×	×	×	×	×
Cucullaea alta Sow.	..	..	×	..	..	..	..	..	×	×	..	×	×	×	×
,, *attenuata* Hutt. ..	×	×	×	..	..	..	..	..	..	..	..	..	×	×	×
,, *australis* (Hutt.) ..	..	..	..	..	×	..	..	×	..	..	..	..	..	..	×
Cylichnella enysi (Hutt.) ..	..	..	..	..	..	..	..	..	..	..	..	..	×	×	×
Cymatium minimum (Hutt.) ..	..	..	..	..	×	×	×	×	..	..	×	..	..	×	×
Cytherea enysi Hutt.	..	..	..	..	..	..	..	..	..	..	..	×	..	×	×
Daphnella neozelanica Sut. ..	×	×	..	..	..	..	..	..	..	..	×	..	..	×	×
**Dentalium ecostatum* T. W. Kirk	..	..	..	..	×	×	×	×	..	..	×	..	..	×	×
,, *mantelli* Zitt. ..	×	×	..	..	×	×	×	×	..	..	×	×	..	×	×
* ,, *nanum* Hutt. ..	..	..	..	..	..	..	..	..	..	..	×	×	..	×	×
,, *solidum* Hutt. ..	..	..	×	..	×	×	×	×	..	×	×	×	×	×	×
**Divaricella cumingi* (Ad. & Ang.)	..	..	..	..	..	..	..	..	..	..	..	..	×	×	×
**Dosinia greyi* Zitt.	×	×	..	..	×	..	..	×	..	×	×	..	×	×	×
* ,, *lambata* (Gould) ..	..	×	..	..	..	..	..	..	..	×	×	..	×	×	×
,, *magna* Hutt.	..	..	..	..	..	..	..	..	..	×	×	..	×	×	×
Drillia awamoaensis (Hutt.) ..	×	×	..	..	×	..	..	×	..	×	×	..	×	×	×
,, *buchanani* (Hutt.) ..	..	..	..	..	..	..	..	..	..	..	×	..	..	×	×
Epitonium browni (Zitt.) ..	..	..	..	×	×	..	..	×	..	..	×	..	..	×	×
,, *elatum* Sut. ..	..	..	..	..	×	..	..	×	..	..	..	..	..	..	×
,, *lyratum* (Zitt.) ..	..	..	..	×	×	×	..	×	×	..	×	×	..	×	×
* ,, *zelebori* (Dkr.) ..	..	..	..	..	..	..	..	..	..	..	×	..	..	×	×
Euthria media (Hutt.) ..	..	..	..	..	..	..	..	..	..	..	×	..	..	×	×
Exilia dalli Sut.	..	..	..	..	×	..	×	×	..	..	..	..	..	..	×
Ficus transennus Sut.	?	?	..	..	..	..	..	..	..	..	..	..	..	..	..
Fulgoraria aculeata (Hutt.) ..	..	..	..	..	×	..	..	×	..	..	..	..	..	..	×
* ,, *arabica* (Mart.) ..	..	..	..	..	×	..	×	×	×	..	×	×	..	×	×
,, ,, *elongata* (Swains.)	..	..	..	..	..	..	×	×	..	..	×	×	..	×	×
,, ,, *turrita* Sut. ..	..	..	..	..	×	..	..	×	..	..	..	..	..	..	×
,, *gracilis* (Swains.) ..	..	..	..	..	..	×	..	×	..	..	..	..	..	..	×
**Fusinus spiralis* (A. Ad.) ..	..	..	..	..	×	×	×	×	..	..	×	..	×	×	×

GUDEX.—*Succession of Tertiary Beds in Pareora District.*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Galeodea senex (Hutt.)	..	..	..	..	×	×	×	×	..	..	..	×	×	×	×
Genota robusta (Hutt.)	..	..	..	..	..	..	..	..	..	..	×	×	..	×	×
Glycymeris cordata (Hutt.)	..	..	..	..	..	..	..	..	..	..	×	..	×	×	×
,, *globosa* (Hutt.)	..	..	..	..	..	..	..	..	..	..	×	..	..	×	×
* ,, *laticostata* (Q. & G.)	..	×	..	..	..	..	×	×	..	..	×	×	×	×	×
Gryphaea tarda Hutt.	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..
Heliacus imperfectus Sut.	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..
Hemiconus ornatus (Hutt.)	..	..	..	..	..	..	..	..	..	..	×	×	..	×	×
Latirus brevirostris (Hutt.)	..	..	..	..	..	..	..	..	..	..	×	×	×	×	×
Leucosyrinx alta (Harris)	..	..	..	..	..	..	..	..	..	..	×	..	×	×	×
Lima colorata Hutt.	..	..	..	..	×	×	×	×	×	..	..	..	..	×	×
,, *imitata* Sut.	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..
,, *laevigata* Hutt.	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..
,, *paleata* Hutt. (?)	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..
**Limopsis aurita* (Brocchi)	×	×	..	..	×	×	×	×	..	..	×	×	×	×	×
,, *catenata* Sut.	..	..	..	..	..	..	..	..	..	×	..	..	×	×	×
,, *zitteli* Iher.	..	..	..	..	..	×	..	×	..	×	×	×	..	×	×
Loripes laminata Hutt.	..	..	..	..	..	..	..	..	..	..	×	..	..	×	×
Macrocallista assimilis (Hutt.)	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..
Mactra chrydea Sut.	..	..	..	..	..	..	..	..	..	..	×	..	..	×	×
* ,, *discors* Gray	..	..	..	..	..	..	..	..	..	..	..	..	×	×	×
* ,, *scalpellum* Reeve	×	×	..	..	..	..	..	..	..	..	×	×	×	×	×
**Malletia australis* (Q. & G.)	..	..	..	..	×	..	×	×	×	..	..	×	..	×	×
**Mangilia protensa* (Hutt.)	..	..	..	..	..	..	×	×	..	..	..	..	..	..	×
Marginella conica Harris	..	..	..	..	..	×	×	×	..	..	..	..	..	..	×
Mesalia striolata (Hutt.)	×	×	..	..	..	..	..	..	..	..	×	..	..	×	×
Miomelon corrugata (Hutt.)	..	..	..	..	×	×	×	×	..	..	×	..	×	×	×
Mitra armorica Sut.	..	..	..	..	×	..	..	×	..	..	..	..	..	..	×
Modiolus dolichus Sut.	..	×	..	..	..	..	..	..	..	..	..	..	×	×	×
Murex zelandicus Q. & G.	..	..	..	..	..	×	×	×	..	..	..	..	..	..	×
**Natica australis* (Hutt.)	..	..	..	..	..	..	..	..	..	..	×	..	..	×	×
* ,, *zelandica* Q. & G.	×	×	..	..	×	..	×	×	..	..	×	..	×	×	×
**Nucula nitidula* A. Ad.	..	..	..	..	..	..	..	..	..	..	..	..	..	×	×
Olivella neozelanica (Hutt.)	..	..	..	..	..	..	..	..	..	..	×	..	..	×	×
Ostrea gudexi Sut.	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..
,, *nelsoniana* Zitt.	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..
Panope orbita (Hutt.)	..	..	..	..	×	×	..	×	..	..	..	..	..	..	×
,, *worthingtoni* (Hutt.)	..	..	×	..	..	..	..	..	..	..	..	×	×	×	×
* ,, *zelandica* (Q. & G.)	..	..	..	..	..	..	..	..	×	..	..	..	..	×	×
Paphia curta (Hutt.)	..	..	..	..	..	..	..	..	..	..	×	×	×	×	×
Pecten burnetti Zitt.	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..
,, *delicatulus* Hutt.	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..
,, *hilli* Hutt.	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..
,, *huttoni* (Park)	..	×	×	×	×	..	×	×	×	×	×	×	×	×	×
,, *scandula* Hutt. (?)	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..
,, cf. *triphooki* Zitt.	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..
,, *williamsoni* Zitt.	..	..	..	×	..	..	..	×	..	..	..	..	..	..	×
Placunanomia incisura Hutt.	..	..	..	..	..	..	..	..	×	..	..	..	..	×	×
* ,, *zelandica* (Gray)	..	..	..	..	×	..	..	..	×	..	×	..	×	×	×
**Polinices amphialus* (Wats.)	..	..	..	..	×	..	×	×	..	..	..	×	..	×	×
,, *gibbosus* (Hutt.)	..	×	×	..	..	×	..	×	..	..	×	×	×	×	×
,, *huttoni* Iher.	..	..	..	..	×	..	×	×	×	..	×	..	×	×	×
,, *ovatus* (Hutt.)	..	..	..	..	×	×	..	×	..	×	×	×	×	×	×
,, *planispirus* Sut.	..	..	..	..	×	..	..	×	..	..	..	..	..	..	×
**Psammobia lineolata* Gray	×	×	..	..	..	..	..	..	..	..	×	×	×	×	×
,, cf. *stangeri* Gray	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..
* ,, *zelandica* Desh.	×	×	..	..	..	..	..	..	..	×	..	×	×	×	×
Ptychatractus nodosoliratus Sut.	..	..	..	..	×	..	..	×	..	..	..	..	..	..	×
**Pupa alba* Hutt.	×	×	..	..	..	..	..	..	..	..	..	..	×	×	×
Sinum cinctum (Hutt.)	..	×	..	..	×	..	..	×	..	..	..	..	..	..	×
,, *miocoenicum* (Sut.)	..	..	..	..	..	..	×	×	..	..	×	..	..	×	×
,, *undulatum* (Sut.)	×	..	..	..	×	×	..	×	..	..	..	..	..	..	×

—	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Siphonalia conoidea (Zitt.) ..	..	..	..	..	×	..	..	×	..	..	..	..	..	..	×
,, *costata* (Hutt.) ..	×	×	..	..	×	×	×	×	..	..	×	×	×	×	×
* ,, *dilatata* (Q. & G.) ..	..	..	..	..	×	..	×	×	..	..	×	×	×	×	×
* ,, *nodosa* (Mart.) ..	..	..	..	..	×	..	×	×	..	..	×	×	×	×	×
,, *subnodosa* (Hutt.) ..	..	..	..	..	..	..	..	..	..	..	×	..	..	×	×
Struthiolaria cincta Hutt. ..	×	×	..	..	..	..	..	..	..	×	..	..	×	×	×
,, *papulosa* (Mart.) ..	..	..	..	..	..	..	..	..	..	..	×	×	×	×	×
,, *spinosa* Hect. ..	..	..	..	..	..	..	..	..	..	..	..	×	..	×	×
,, *tuberculata* Hutt. ..	×	×	×	..	..	..	..	..	..	..	×	×	×	×	..
Surcula fusiformis (Hutt.) ..	..	..	×	..	×	×	×	×	×	..	×	×	×	×	×
**Tellina glabrella* Desh. ..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..
Terebra orycta Sut.	..	..	..	..	×	..	..	×	..	..	×	×	×	×	×
,, *pareoraensis* Sut. ..	..	..	..	..	×	..	×	×	..	..	×	×	×	×	×
* ,, *tristis* Desh.	×	×	..	..	..	..	..	..	..	..	×	..	..	×	×
Teredo heaphyi Zitt.	×	×	..	..	×	..	..	×	..	..	..	..	..	..	×
,, *directa* Hutt.	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..
Turbonilla prisca Sut. ..	..	..	..	..	×	..	..	×	..	..	..	..	..	..	×
**Turritella carlottae* Wats. ..	..	..	..	..	..	×	×	×	..	..	..	×	..	×	×
,, *cavershamensis* Harris	..	×	..	..	×	×	×	×	..	×	×	×	×	×	×
,, *concava* Hutt. ..	..	..	..	..	×	×	..	×	..	..	..	×	×	×	×
,, *patagonica* Sow. ..	×	×	..	..	×	..	..	×	..	..	..	..	..	..	×
* ,, *rosea* Q. & G. ..	..	..	..	..	×	×	..	×	..	..	..	×	..	×	×
,, *semiconcava* Sut. ..	×	×	..	..	..	×	×	×	..	..	..	..	×	×	×
* ,, *symmetrica* Hutt. ..	×	×	×	..	..	..	..	×	×	..	×	..	..	×	×
Typhis maccoyi T.-W. ..	..	×	..	..	×	×	×	×	..	..	..	..	..	×	×
Venericardia pseutes Sut. ..	×	×	..	..	..	..	..	..	..	×	..	×	×	×	×
* ,, *purpurata* (Desh.) ..	..	..	..	..	×	×	..	×	..	×	..	..	..	×	×
,, *zelandica* (Desh.) var.	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..
Vexillum apicale (Hutt.) ..	..	..	..	..	..	..	×	×	..	..	..	..	..	..	×
,, *rutidolomum* Sut. ..	×	×	..	..	×	..	×	×	..	..	..	..	..	×	×
**Zenatia acinaces* Q. & G. ..	..	..	..	..	..	..	..	..	..	..	×	×	×	×	×

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ART. XXVII.—*The Tertiary Molluscan Fauna of Pakaurangi Point, Kaipara Harbour.*

By P. MARSHALL, M.A., D.Sc.

[*Read before the Wanganui Philosophical Society, 19th December, 1917; received by Editors, 31st December, 1917; issued separately, 24th June, 1918.*]

Plates XVIII–XXII.

IN a previous paper* a list was given of the Mollusca that had been collected in this locality. Further collections have since been made which have added considerably to the number of the species. Descriptions and figures are given of all the new species. A discussion of the nature of the fauna will be given after the descriptions.

Vaginella torpedo n. sp. (Plate XXII, figs. 7, 8.)

Shell of moderate size, 18 mm. by 3·5 mm. Form cylindrical with a conical termination. Slightly compressed at the anterior end. Shell porcellanous with a shining surface. With a low-power pocket-lens a series of fine longitudinal lines can just be made out.

Seven good specimens were obtained. Type in the Wanganui Museum.

Calliostoma gracilis. (Plate XVIII, figs. 1, 1*a*.)

Shell small: height, 7 mm.; breadth, 10 mm.: trochoidal. Spire short, of 3 whorls. Aperture oval. Columella slightly excavated. Protoconch consisting of 2 whorls. Outline of each whorl of the spire slightly concave. Three small spiral threads near the posterior suture of each whorl and a larger one near the anterior suture. Body-whorl with a large number of fine spiral threads in addition to those on the other whorls. Base with similar small spiral lines, with two large and prominent ones that divide the base into three approximately equal parts. Inner layer of the shell highly nacreous.

One specimen, in good condition. Type in the Wanganui Museum.

Heliacus aucklandicus. (Plate XVIII, figs. 2, 2*a*.)

Shell small: height, 3 mm.; breadth, 10 mm. Form obtusely conical. Spire short, consisting of 5 whorls each with a straight outline. Aperture regular. Umbilicus very large, with a strongly crenulated margin. Ornamentation: Each whorl with 4 beaded cinguli; the two most prominent of these border the anterior and posterior sutures closely. Base smooth except for irregular ribs radiating outward from the crenulated margin of the umbilicus.

One specimen only, in a good state of preservation. Type in the Wanganui Museum.

Epitonium tricinctum n. sp. (Plate XIX, figs. 8, 12.)

Shell small and slender: length, 8 mm.; breadth, 3 mm. Spire of 6 whorls, but it is not complete. Outline of whorls strongly convex. Suture deep. Aperture not preserved. Ornamentation: On each whorl 3 strong spiral lines. The uppermost of these is the most prominent: it is situated

* *Trans. N.Z. Inst.*, vol. 49, pp. 447–48, 1917.

a little behind the middle of the whorl, and the other two lie between it and the suture in front. Each of the spiral lines is continuous over the radial lines, of which there are 18 in each whorl.

Only one specimen was found, and it is somewhat incomplete, but the ornamentation is quite distinct from that of any other New Zealand species. Type in the Wanganui Museum.

Fusinus corrugatus n. sp. (Plate XXII, figs. 9, 10.)

Shell of moderate size, fusiform, 21 mm. by 5 mm. Spire a little less than half the length of the shell, consisting of 6 whorls, each strongly convex. Aperture oval, and narrowing anteriorly into a moderately long canal. Protoconch of 3 whorls, smooth. Ornamentation: 7 rounded axial costae in each whorl, extending from suture to suture, but much higher on the keel than elsewhere. Spiral threads some 6 in number in each whorl but extremely unequal, the one that marks the keel being much more prominent than all the others, and the one anterior to it also much larger than the rest. The spiral lines are particularly strong on the costae, where they form prominent projections. Very small spiral threads between every pair of larger ones. Suture not pronounced, wavy. Body-whorl with similar ornamentation, the spiral lines being continued to the end of the beak, but they are much less prominent there.

Two specimens, one almost complete, the other without its beak. Type in the Wanganui Museum.

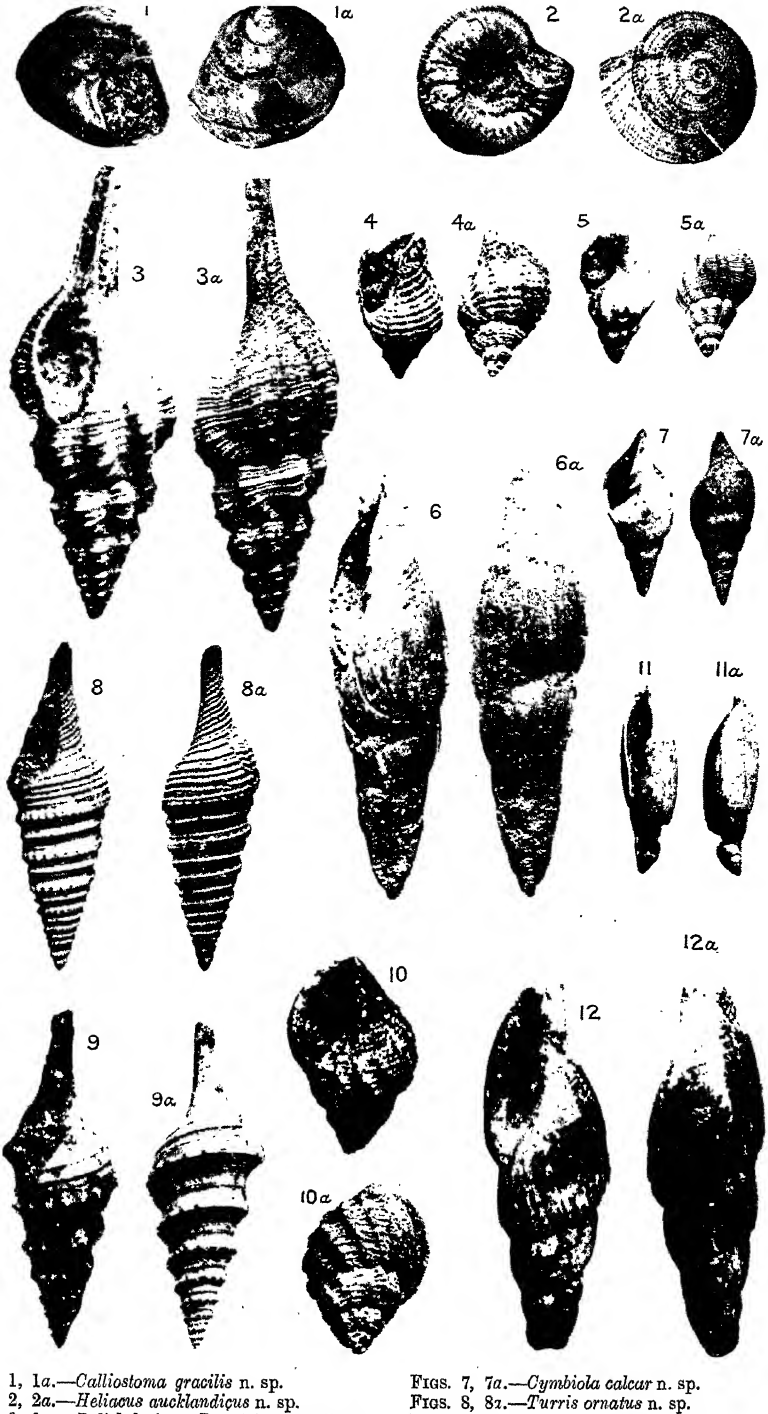
Dolicholatirus (Pseudolatirus) ornatus n. sp. (Plate XVIII, figs, 3, *3a.*)

Shell of moderate size, 25 mm. by 10 mm. Shape fusiform. Spire of 6 whorls, protoconch of 2 whorls. Suture compressed wavy. Aperture pyriform, almost half the total length of the shell, and produced anteriorly into a long canal but somewhat truncated posteriorly. Outer lip thin, with 12 internal projections. Columella slightly bent inwards where the aperture narrows into the anterior siphon. Columella slightly callous, smooth but furnished with 5 small projections, 2 of which are the terminal points of columellar folds. At the base of the aperture 3 small projections. Ornamentation: 7 prominent radial costae on each whorl. The costae in successive whorls are not arranged in a straight line but form a spiral directed backwards. Each whorl with a large number of spiral threads. About every fourth thread is much larger and forms prominent elevations where they cross the costae. Strong lines of growth. On the body-whorl the costae extend to the beginning of the anterior canal.

Six specimens. Type in the Wanganui Museum.

Siphonalia flexuosa n. sp. (Plate XXII, figs. 11, 12.)

Shell of moderate size, of oval shape, 28 mm. by 17 mm. Spire of 6 whorls rapidly decreasing in size. Aperture rather less than half the length of the shell. Outer lip moderately thick and ornamented internally by several short spiral lines. Anterior canal bent sharply to the right and of moderate length. Ornamentation: 10 radial costae on each whorl: these extend to the anterior suture but barely reach the posterior one: they are more distinct in the upper whorls. Suture strongly margined anteriorly. Posterior portion of each whorl concave in outline. All parts of the whorls have spiral ribs, which are large and rounded. There is usually one small thread between each pair of ribs. Large spiral threads are less pronounced on the beak, and the interstitial threads are more numerous. Growth-lines are numerous and conspicuous on the body-whorl.



Figs. 1, 1*a*.—*Calliostoma gracilis* n. sp.
Figs. 2, 2*a*.—*Heliacus aucklandicus* n. sp.
Figs. 3, 3*a*.—*Dolicholatirus* (*Pseudolatirus*) *ornatus* n. sp.
Figs. 4, 4*a*.—*Phos kaiparaensis* n. sp.
Figs. 5, 5*a*.—*Phos spiralis* n. sp.
Figs. 7, 7*a*.—*Cymbiola calcar* n. sp.
Figs. 8, 8*a*.—*Turris ornatus* n. sp.
Figs. 9, 9*a*.—*Turris kaiparaensis* n. sp.
Figs. 10, 10*a*.—*Borsonia* (*Cordieria*) *ovalis* n. sp.
Figs. 11, 11*a*.—*Crenilabium zelandicum* n. sp.
Figs. 12, 12*a*.—*Cymbiola masefieldi* n. sp.

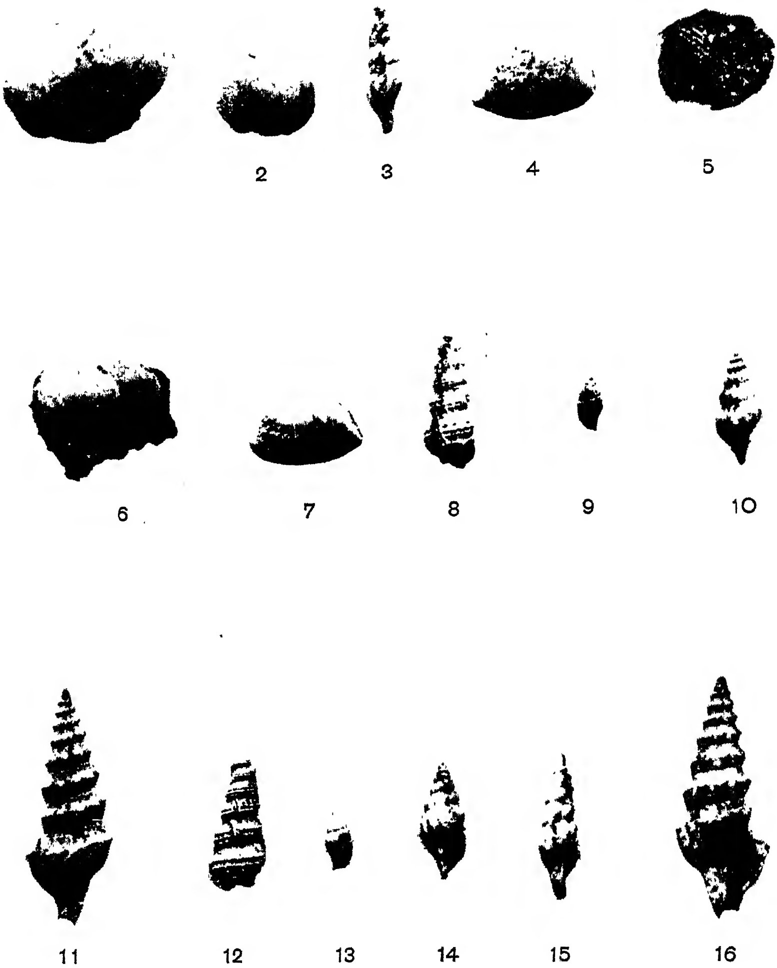


FIG. 1.—*Tellina* (*Arcopagia*) *inconspicua* n. sp.
FIG. 2.—*Tellina* (*Arcopagia*) *inconspicua* n. sp. (× 2.)
FIG. 3.—*Surcula nitens* n. sp.
FIG. 4.—*Corbula nitens* n. sp.
FIG. 5.—*Sarepta aucklandica* n. sp. (× 2.)
FIG. 6.—*Sarepta aucklandica* n. sp.
FIG. 7.—*Corbula nitens* n. sp.
FIG. 8.—*Epitonium tricinctum* n. sp.
FIG. 9.—*Mitrella inconspicua* n. sp.
FIG. 10.—*Mangilia axialis* n. sp.
FIG. 11.—*Drillia tenuispiralis* n. sp.
FIG. 12.—*Epitonium tricinctum* n. sp.
FIG. 13.—*Mitrella inconspicua* n. sp.
FIG. 14.—*Mangilia axialis* n. sp.
FIG. 15.—*Surcula nitens* n. sp.
FIG. 16.—*Drillia tenuispiralis* n. sp.

(All figs. except 2 and 5 × 3.)

Several specimens, in good condition. Type in the Wanganui Museum.

This species most closely resembles *S. costata*, but the anterior canal is more bent and the costae less pronounced, though the spiral ribs are more distinct.

Coptochetus zelandicus n. sp. (Plate XXII, fig. 13.)

Shell of moderate size, 24 mm. by 8 mm., of a fusiform shape, with a spire of 5 whorls. Whorls slightly convex in outline and gradually decreasing in size. Body-whorl somewhat incomplete. Aperture narrow and extended somewhat anteriorly into a moderately long canal. Columella smooth and almost straight. Ornamentation: Each whorl has 18 or 19 radial ribs. The ribs are rounded, continuous, and of equal height from suture to suture. The ribs are crossed by about 9 spiral threads of small size on each whorl. Suture with a sharp border on the anterior margin. Body-whorl with similar ornamentation to that of the spire. The radial ribs appear to extend to the end of the anterior canal, though the imperfect condition of the specimen does not show this clearly.

One specimen only, in an imperfect state. Type in the Wanganui Museum.

I am indebted to Mr. Suter for suggesting that the specimen should be referred to this genus, though he states that he is not certain that it is correct.

The genus *Coptochetus* appears to be restricted to the Oligocene and Eocene. It occurs in Europe and Australia.

Phos kaiparaensis n. sp. (Plate XVIII, figs. 4, 4*a*.)

Shell small and oval, 7 mm. by 5 mm. Spire of 5 whorls, three of which are apparently the protoconch. Aperture less than half the length of the shell, broadly oval but narrowing anteriorly to a very short canal slightly bent backwards. Ornamentation: 10 radial costae on each whorl, broad and rounded but most prominent near the anterior suture. The whorls of the protoconch have no costae. There are a large number of spiral ridges on each whorl, well rounded, and continuous across the costae. On the protoconch the threads are relatively larger and less numerous. On the body-whorl the costae decrease in size anteriorly and end at about two-thirds of its length. The spiral ridges extend to the end of the short siphon. Suture impressed but not bordered.

One specimen only, in good condition. Mr. Suter thinks that it is not mature Type in the Wanganui Museum.

Phos spiralis n. sp. (Plate XVIII, figs. 5, 5*a*.)

Shell small, oval, 10 mm. by 6 mm. Spire consisting of 5 whorls rapidly decreasing: two of these are the protoconch. Aperture oval, rather less than half the length of the shell. The aperture narrows somewhat anteriorly and forms a short canal. There is a slight callosity on the columella, which is a little bent over to the left. Ornamentation: Axial costae 13 in number, broad and low, extending from suture to suture. They are crossed by a number of relatively large spiral ridges. There are 5 of these in the penultimate whorl, and they cross the costae without diminution. Protoconch smooth. Outline of whorls convex, suture impressed. The costae on the body-whorl become less prominent towards the anterior end, but the spiral threads are continuous.

One specimen only, in a good state of preservation. Mr. Suter thinks that it is not mature. Type in the Wanganui Museum.

Cymbiola masefieldi n. sp. (Plate XVIII, figs. 12, 12*a*.)

Shell of moderate size, 21 mm. by 8 mm. The type specimen, however, is not quite complete: if it were, the length would probably be 25 mm. Shape fusiform. Spire of 5 whorls separated by a deep suture. Each whorl with a convex outline rising steeply from the posterior suture but sloping gently anteriorly. Body-whorl about two-thirds of the total length. Aperture about one-third of the length of the shell, narrowly oval, extended anteriorly into a short canal. Columella without callosity but with two distinct plaits. Ornamentation slight. Two or three narrow spiral grooves on the posterior portion of each whorl. Base with about 12 spiral grooves filling all the space between the base of the aperture and the apex of the canal. Growth-lines are distinct on all the whorls.

Three specimens, in rather an imperfect condition. Type in the Wanganui Museum.

Cymbiola nitens n. sp. (Plate XVIII, figs. 6, 6*a*.)

Shell of moderate size, 26 mm. by 8 mm. Spire of moderate length, consisting of 5 or 6 whorls. Each whorl slightly convex, with a steep slope behind. Body-whorl about two-thirds the length of the shell, aperture about one-third. Aperture narrow, extended anteriorly into a short canal. Columella with no callus but with 2 strong folds of almost equal size. Ornamentation: Surface smooth and polished. A few spiral grooves in each whorl: these are deeper and more pronounced near the upper part of each whorl. Body-whorl with 2 of these grooves near its posterior end, with 13 grooves near its anterior end, where it is prolonged into a short canal. Growth-lines distinct.

This species is very closely related to *C. masefieldi*, but it has more numerous but less distinct spiral grooves, and the outline of the whorls is less convex.

Three specimens only, one of which is in good condition. Type in the Wanganui Museum.

Cymbiola calcar n. sp. (Plate XVIII, figs. 7, 7*a*.)

Shell small, 9 mm. by 4 mm. Shape ovate. Spire rather short, of 7 whorls, rapidly decreasing: three of these constitute the protoconch. Body-whorl distinctly longer than the rest of the shell. Aperture nearly one-half the length of the shell, ovate. Outer lip not preserved; columella without callosity, but with 2 sharp folds, the posterior of which is sharper than the anterior and more oblique than it. A well-developed but short anterior canal. Whorls slightly convex, steep on the posterior side but gently sloping on the anterior side. All the whorls have narrow spiral grooves. Body-whorl with 6 strong distant narrow ridges on the anterior part. Lines of growth distinct.

One specimen only, in good condition. Type in the Wanganui Museum.

Mitrella inconspicua n. sp. (Plate XIX, figs. 9, 13.)

Shell minute, 4 mm. by 1·5 mm., shortly fusiform. Spire of 6 whorls almost flat in profile. Aperture considerably less than one-half the length of the shell. Outer lip starting at a sharp angle, thick at first, but becoming thin towards the short anterior canal. Columella with 6 distinct spiral lines extending outward over the body-whorl. Protoconch of 3 smooth whorls. Ornamentation: Whorls almost smooth, though with obscure irregular radial lines. Suture impressed.

One specimen only, in good condition. Type in the Wanganui Museum.

Mr. Suter thinks that this species is closely related to *M. choava* Reeve, but is distinct from it.

Ancilla spinigera n. sp. (Plate XX, figs. 1, 1*a*.)

Shell of moderate size, 23 mm. by 14 mm., oval in shape, but the spire is extremely short, and is completely covered with a callus from which the protoconch projects as a small spine. Aperture three-quarters the length of the shell. The grooves in the columella are well marked, but towards the base of the columella it becomes extremely callous. Fasciole well marked. The body-whorl has distinct growth-marks, and on the callus there are some indistinct radial marks. The callus extends forward from the columella over the body-whorl for about one-third of its circumference, reaching as far as the fasciole. Three specimens, two of them in good condition. Type in the Wanganui Museum.

Ancilla cincta n. sp. (Plate XX, figs. 2, 2*a*.)

Shell of moderate size, 28 mm. by 13 mm.; form elliptical, the protoconch projecting as a sharp point. Spire short, and completely covered with callus. Aperture nearly two-thirds the length of the shell. Columella callous, and the callosity extends forward a short distance over the body-whorl. On the callosity which covers the spire a few spiral ridges are rather evident: these apparently indicate the whorls of the spire, which thus seems to consist of 4 whorls. Lines of growth are distinct over that part of the body-whorl that is not covered with callus.

One specimen only, in a fair state of preservation. Type in the Wanganui Museum.

Surcula latiaxialis n. sp. (Plate XX, figs. 3, 3*a*.)

Shell rather large, 34 mm. by 11 mm. Shape fusiform, with a long spire of 5 whorls, which are strongly convex. Aperture slightly longer than the spire, but oval in shape, though rather prolonged anteriorly. Columella distinctly bulging at the point where the aperture narrows to the anterior canal. Ornamentation: 7 prominent axial costae in each whorl; these extend to the anterior suture, which bends forward slightly at the points where the axials reach it. Posteriorly the axial sutures stop short of the suture; anteriorly the sutures are margined by a strong ridge, which is itself marked by extremely fine spiral lines. Whorls marked by numerous fine spiral lines, which traverse the axial costae as well as the other parts of the whorl. The spiral lines are finer and more numerous in the posterior part of the whorl, and are coarsest where they cross the axials. These are crossed by irregular lines of growth, the form of which indicate that the anal sinus was relatively shallow. The outer lip is not sufficiently well preserved to demonstrate that point.

This species is rather similar to *S. fusiformis* Hutton, from which it differs in the smaller number of its broad axial costae, which number 7 in place of 11; by the spiral striation of the posterior part of each whorl, and by the bordered and wavy suture.

Two specimens only, one of which is nearly complete. Type in the Wanganui Museum.

Surcula nitens n. sp. (Plate XIX, figs. 3, 15.)

Shell small, fusiform, 8 mm. by 2·5 mm. Spire of 5 convex tapering whorls, half as long again as the aperture. Suture slightly bordered

anteriorly. Aperture oval, anal notch rather shallow; anterior canal of moderate length. Ornamentation: 10 broad and rounded radial costae in each whorl. These costae extend to the anterior but not to the posterior suture. Surface of the shell quite smooth except at the end of the beak, which has 10 feeble spiral lines. Protoconch consists of 3 whorls.

The smoothness of the surface distinguishes this species.

Two specimens, in good condition. Type in the Wanganui Museum.

Surcula ordinaria n. sp. (Plate XX, figs. 4, 4*a*.)

Shell of rather large size, 32 mm. by 8 mm.; fusiform, with a tapering spire of 6 or 7 whorls. The narrow aperture is half the length of the shell, and is prolonged into a long anterior canal. The outer lip is thin, with a broad shallow anal notch near the suture but separated from it. Inner lip smooth. Protoconch smooth, of 4 whorls. Ornamentation is not conspicuous. In each whorl the posterior suture is margined with a broad spiral swelling. On this there are fine barely visible spiral striations, which are also to be distinguished on all the posterior part of the whorl as far as the keel. This is well marked, and has about 12 rounded tubercles on each whorl. Anterior to the keel there are about 9 spiral lines, more conspicuous than those posterior to it. Lines of growth numerous and well marked. Body-whorl with numerous spiral lines, about every fourth of which is larger than the others. Fifteen of these larger lines can be distinguished.

Three specimens, two of which are in good condition. Type in the Wanganui Museum.

Turris ornatus n. sp. (Plate XVIII, figs. 8, 8*a*.)

Shell small, fusiform, 18 mm. by 6 mm. Spire of 6 whorls, each with a pronounced keel. Suture impressed. Body-whorl rather more than half the total length, but aperture rather less than half. Aperture oval in form and produced anteriorly into a long canal. Anal notch rather deep. Columella nearly straight and covered with a thin callus. Ornamentation: A broad keel with about 24 rounded tubercles on each whorl. A second smaller keel posterior to this, and a third near the posterior suture, but the last is quite small: both of these are slightly rough but have no well-defined tubercles. Two slender spiral lines in front of the keel and one on the posterior side. Abundant and prominent growth-lines. Body-whorl with a number of nearly equal spiral ridges in front of the keel, and these are crossed by numerous growth-lines.

Two good specimens and other fragments. Type in the Wanganui Museum.

Turris kaiparaensis n. sp. (Plate XVIII, figs. 9, 9*a*.)

Shell small, fusiform, 20 mm. by 7 mm. Spire of 7 whorls, strongly keeled. Body-whorl about half the length of the shell. Aperture about one-third, oval, rather obtuse posteriorly but anteriorly produced into a long canal. Columella nearly straight and very slightly callous. Anal notch deep. Ornamentation: A prominent keel with a slight median groove bearing 22 rounded tubercles in each whorl. Eleven thin spiral threads posterior to the keel, the one nearest to the suture being much the largest. Spiral threads crossed by many thin lines of growth. Body-whorl with 3 prominent rather diverging spiral lines anterior to the keel: the middle of these passes through the point where the outer lip joins the shell; the

anterior one passes into the aperture. There are many other spiral threads on the body-whorl, every alternate one being relatively small.

A very common species at Pakaurangi Point, no fewer than forty specimens being obtained. Type in the Wanganui Museum.

Borsonia (Cordieria) ovalis n. sp. (Plate XVIII, figs. 10, 10*a*.)

Shell small, oval, 13 mm. by 9 mm. Spire short, consisting of 4 rapidly diminishing whorls. Outline of whorls slightly convex. Aperture oval, rather less than half the length of the shell. Outer lip thick, inner lip not callous. The columella with 3 distinct folds. Aperture obtuse anteriorly. Ornamentation: Each whorl with about 15 radial costae slightly raised and continuous from suture to suture: these costae are turned slightly backward. A number of sharp spiral threads, which, however, are interrupted, on the costae. Suture impressed and not bordered. On the body-whorl the costae decrease anteriorly, and are not distinct on the base. Many of the spiral threads, however, continue into the aperture.

One specimen only, in a good state of preservation. I am indebted to Mr. Suter for placing this specimen generically. Type in the Wanganui Museum.

Drillia tenuispiralis n. sp. (Plate XIX, figs. 11, 16.)

Shell small, turreted, 12 mm. by 4 mm.; fusiform in shape, with a tapering spire consisting of 7 whorls. Outline of each whorl strongly convex. Aperture rather more than one-quarter the length of the shell, with a short anterior canal and a deep anal slit. Each whorl with 6 prominent radial costae, which extend from the anterior suture for two-thirds of the breadth of the whorl. At this point they terminate abruptly, and leave the posterior portion of the whorl almost smooth. The anterior part of each whorl is marked with numerous extremely fine spiral lines. On the body-whorl the radial costae are far less prominent, and towards the outer lip they are replaced by prominent lines of growth. Spiral threads are continued to the end of the anterior canal. A slight callosity on the columella.

Mr. Suter remarks that this species comes nearest to *D. costifer* Suter.

A single specimen, but in excellent condition. Type in the Wanganui Museum.

Mangilia axialis n. sp. (Plate XIX, figs. 10, 14.)

Shell small, fusiform, 6 mm. by 2·5 mm. Spire consisting of 5 strongly convex whorls. Aperture oval, more than one-third but less than one-half the length of the shell. A very short anterior canal. Outer lip thick. Columella smooth. Ornamentation: Strong axial ribs to the number of 12 on each whorl: they are rounded and extend from suture to suture, and are bent slightly forward in the lower part, though broader in the middle than elsewhere. A large number of fine spiral lines, which are more prominent in the interstices than on the ribs. Body-whorl with the same ornamentation, the axial ribs extending almost to the end of the short canal. Protoconch of 3 perfectly smooth whorls.

Rather similar to *M. tenuispiralis*, but the spiral lines of *M. axialis* are finer, the axial ribs less pronounced, the body-whorl ribbed, and the form is more slender than in *M. tenuispiralis*.

Three specimens, one in very good condition. Type in the Wanganui Museum.

Conus (Leptoconus) lyratus n. sp. (Plate XX, figs. 5, 5*a*.)

Shell of moderate size, 28 mm. by 10 mm. Spire short, about one-fifth the length of the body-whorl. Five whorls, each slightly convex in outline. Each whorl rising by a decided step from the anterior suture. Aperture narrow but expanding slightly anteriorly. Ornamentation: Whorls smooth except for numerous distinct lines of growth which extend completely across them. Body-whorl with distinct spiral lirae over its whole surface, though they are more distinct in the anterior than in the posterior portion. Lines of growth on the body-whorl are not numerous and not distinct.

A single specimen, in good condition. Type in the Wanganui Museum.

Conus convexus n. sp. (Plate XX, figs. 6, 6*a*.)

Shell of moderate size, 27 mm. by 13 mm. Spire conical, about one-sixth the length of the shell, and consisting of 5 whorls. Outline of each whorl convex. Aperture linear, narrow. Ornamentation: Whorls of the spire lyrate with about 10 lirae, which are more pronounced on the anterior than on the posterior part of the whorl. Lines of growth not distinct. Body-whorl has fairly well-marked lines of growth, but it is otherwise smooth except for some 10 spiral lirae near the anterior end.

A single specimen, in good condition. Type in the Wanganui Museum.

Conus (Lithoconus) abruptus. n. sp. (Plate XX, figs. 7, 7*a*.)

Shell of moderate size, conical, 20 mm. by 11 mm. Spire of 5 whorls, almost flat, and from it the protoconch of 3 whorls projects sharply. Aperture narrow. Columella with a spiral groove near its anterior end. Ornamentation: The whorls of the spire each with about 5 spiral lirae crossed by numerous growth-lines. Suture moderately deep. Body-whorl with numerous but indistinct growth-lines. Eleven distinct spiral lirae near the anterior end. Otherwise the surface is quite smooth.

One specimen, in good condition. This subgenus has not previously been recorded from New Zealand. Type in the Wanganui Museum.

Crenilabium zelandicum n. sp. (Plate XVIII, figs. 11, 11*a*.)

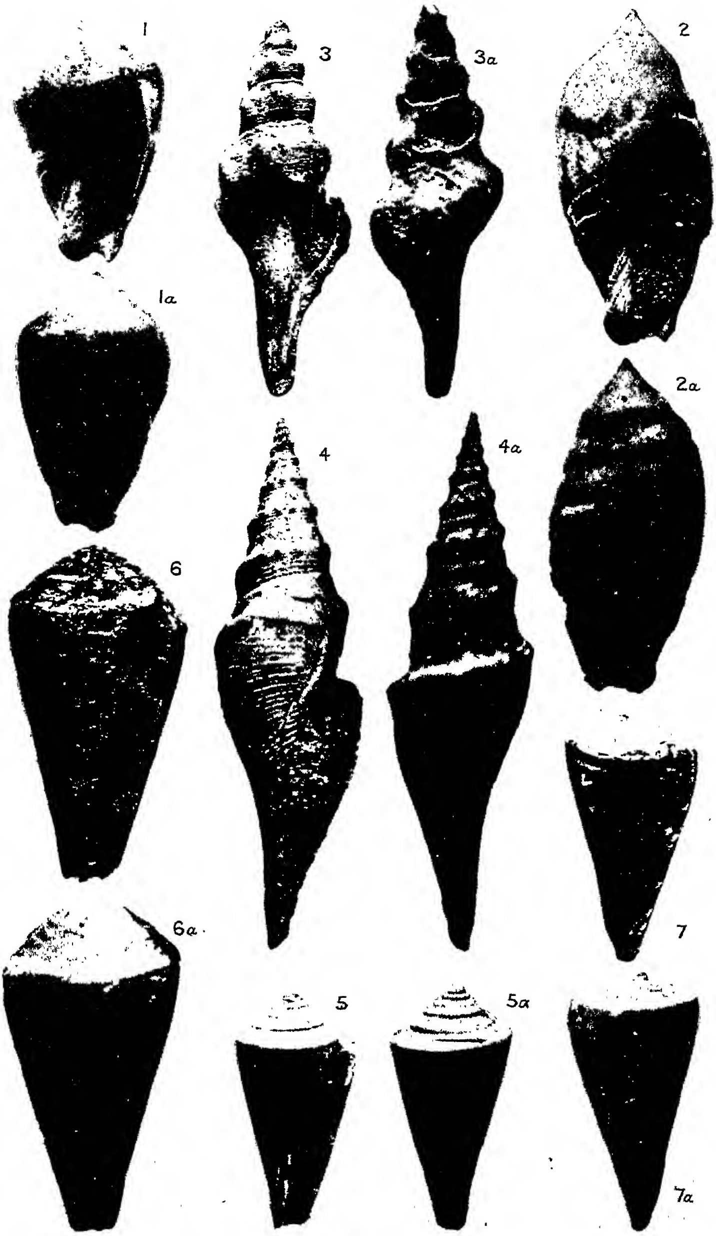
Shell small, 10 mm. by 3 mm., tapering. Spire evidently short, but only one whorl remains. Aperture more than half the length of the shell, narrow below but rapidly widening in the middle. A short anterior canal. Outline of whorl almost flat. Ornamentation: A series of rounded spiral lines which extend to the anterior end of the shell. Columella with a thin fold.

One specimen only, somewhat imperfect. It is, however, certainly rightly placed in this genus, which has not previously been recorded from New Zealand. Type in the Wanganui Museum.

Anomia poculifera n. sp. (Plate XXI, figs. 1, 1*a*.)

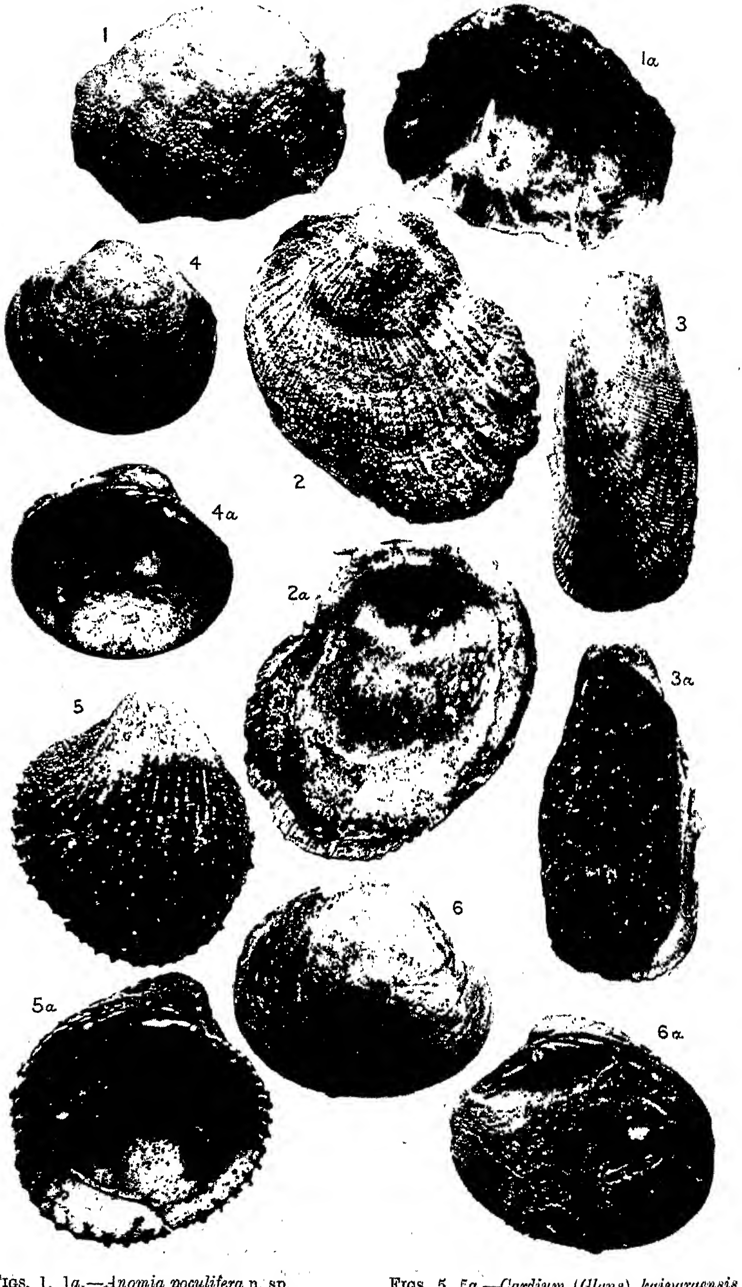
Shell of small size: height, 25 mm.; length, 18 mm. Shape rather obtusely oval. Shell thin and inequilateral, with a nacreous interior. Right valve strongly convex. Anterior end somewhat truncated, posterior end somewhat longer. Foramen moderate, the processes united. Sculpture: 7 large rounded radiating ribs, somewhat bent, and extending from the umbo to the ventral margin. Surface covered with small semilunar cups just in contact with one another and with the convex side nearest the umbo. Muscular impression large.

A single specimen of the right valve, in good condition. Type in the Wanganui Museum.



Figs. 1, 1*a*.—*Ancilla spinigera* n. sp.
Figs. 2, 2*a*.—*Ancilla cincta* n. sp.
Figs. 3, 3*a*.—*Surcula latiaxialis* n. sp.
Figs. 4, 4*a*.—*Surcula ordinaria* n. sp.
Figs. 5, 5*a*.—*Conus* (*Leptoconus*) *lyratus* n. sp.
Figs. 6, 6*a*.—*Conus convexus* n. sp.
Figs. 7, 7*a*.—*Conus* (*Lithoconus*) *abruptus* n. sp.

(All figs. × 2.)



FIGS. 1, 1a.—*Anomia poculifera* n. sp.
FIGS. 2, 2a.—*Spondylus aucklandicus* n. sp.
FIGS. 3, 3a.—*Mytilus torquatus* n. sp.
FIGS. 4, 4a.—*Dosinia tumida* n. sp.
FIGS. 5, 5a.—*Cardium* (*Glans*) *kaiparaensis* n. sp. (× 1½.)
FIGS. 6, 6a.—*Macrocallista sculpturata* n. sp.

(All figs. except 5 and 5a × 2.)

Sarepta aucklandica n. sp. (Plate XIX, figs. 5, 6.)

Shell small and thin: height, 9 mm.; length, 6 mm. Shape semi-orbicular. Umbo fairly prominent, almost in the middle of the dorsal margin. Ventral margin circular. Dorsal margin descending slowly behind but gently rounded in front. Surface of the shell smooth and almost polished, though faint concentric lines can be distinguished. About 9 small teeth can be distinguished on either side of the umbo, but they commence rather more closely to it on the posterior than on the anterior side. Ligament-pit triangular and directed forward.

Not very common. Only two good valves (both left) were found. I am indebted to Mr. Suter for information as to the correct place of this species in classification. Type in the Wanganui Museum.

Mytilus torquatus n. sp. (Plate XXI, figs. 3, 3*a*.)

Shell small, elongated, inflated: height, 22 mm.; length, 14 mm.; thickness, 9 mm. Inflated anteriorly, compressed posteriorly. Slightly winged about the middle. Beak acute, strongly curved anteriorly. Dorsal margin ascending for a short distance, then bent quickly through an angle of 70°, forming a straight line along the anterior margin. Ventral margin gradually rounded, returning with a gradual sweep to the dorsal margin. Surface finely striated. The striae ramify repeatedly along the central line, then extend without further branching to the margin. Striae rounded, very fine on the anterior slope, about as wide as the interstices. They are crossed by very wide concentric undulations and by small cross-threads.

Two specimens only, both right valves, in good condition. Closely related to *M. huttoni* Cossmann = *M. striatus* Hutton.

Spondylus aucklandicus n. sp. (Plate XXI, figs. 2, 2*a*.)

Shell of moderate size, only 20 mm. high and 30 mm. long. Strongly inequilateral with a considerable posterior expansion. Hinge-line straight with a typical provinculum. On the left valve the area is small and almost linear. Umbo not prominent. Crural teeth very large and with 2 or 3 crenulations on the dorsal side. Ligament-pit distinct, with a well-marked ridge on either side. Ornamentation: One or two broad concentric undulations crossed by a number of scaly but not spiny radiating ridges of extremely unequal size. Generally 3 or 4 smaller ribs between the larger ones. The ribs are somewhat irregularly curved, and are continued to the margin, near which they are discernible also on the inner side. On the inner surface, however, they only extend as far as the pallial line.

Two specimens only, one of which is in a very good state of preservation. Type in the Wanganui Museum.

No species of this genus has previously been recorded from the Tertiary deposits of New Zealand, but Professor Woods has lately recorded a specimen, too imperfect for description, from the Cretaceous rocks of North Canterbury. There is also a very large specimen of *Spondylus* in the Auckland Museum which is labelled as coming from Hawke's Bay.

Dosinia tumida n. sp. (Plate XXI, figs. 4, 4*a*.)

Shell small, ovato-orbicular: height, 17 mm.; length, 20 mm.; thickness, 7 mm. Dorsal margin sloping gently posteriorly and developing gradually into the almost circular curve of the ventral margin. Inner surface of the margin delicately crenulated. Umbo fairly prominent and distinctly bent anteriorly. Sculpture a fine concentric striation with strongly incised concentric grooves at intervals. Hinge-plate rather small.

Posterior cardinal tooth in the left valve less markedly bifid than in *D. greyi* Zittel, but well separated from the posterior cardinal tooth. Anterior lateral tooth small, but the posterior lateral large, long, and sharp.

A single left valve, in good condition. Type in the Wanganui Museum.

This species is closely related to *D. greyi* Zittel.

Cardium (Glans) kaiparaensis n. sp. (Plate XXI, figs. 5, 5*a*.)

Shell small, nearly orbicular: height, 30 mm.; length, 35 mm.: somewhat inequilateral and ventricose. Umbo pointed well forward and strongly incurved. Anterior end the shorter and regularly rounded. Dorsal margin gently sloping and ventral margin broadly rounded. Sculpture: The surface is coarsely ribbed, some 35 ribs being present. The ribs are narrower than the interstices, sharp and strongly nodulose. Interstices crossed by numerous fine concentric threads, which do not cross the ribs. Margin sharply dentate. Hinge-plate bow-shaped. Left valve with 1 large cardinal tooth, 1 large and long posterior lateral, and 1 short anterior lateral. Right valve: cardinal tooth long and slender; posterior lateral long, and anterior lateral small.

A common species at Pakaurangi Point, but the shells vary greatly in size. Type in the Wanganui Museum.

Tellina (Arcopagia) inconspicua n. sp. (Plate XIX, figs. 1, 2.)

Shell small, very thin, broadly oval: length, 14 mm.; height, 8 mm.; thickness, 4 mm.: slightly compressed, somewhat inequilateral. Beaks rather produced, situated a little behind the middle. Dorsal edge straight, ventral margin strongly rounded. Valves equally convex. Sculpture consisting of numerous fine rather irregular concentric rounded ridges. A large rounded radiating rib on the posterior portion of the right valve. In the right valve the two cardinal teeth are of equal size. The anterior lateral tooth is much nearer to the cardinals and is much larger than the posterior tooth.

Not uncommon, but the thin and fragile nature of the shell makes it difficult to obtain good specimens. Type in the Wanganui Museum.

Macrocallista sculpturata n. sp. (Plate XXI, figs. 6, 6*a*.)

Shell small, broadly ovate: height, 20 mm.; width, 25 mm. Dorsal margin arched. Anterior margin at first straight, then arched and rounded. Ventral and posterior margins well rounded. The 3 cardinal teeth are well marked and large. The first anterior lateral is small and obtuse. The second anterior lateral is long and reaches to the margin. The 2 posterior lateral teeth are sharp. Sculpture: A fine general concentric striation is nearly obsolete. On the posterior portion a series of fine wavy striations nearly parallel to the margin. On the anterior portion an angular or V-shaped sculpture can be seen over a portion of the surface.

A single right valve in a good state of preservation. Type in the Wanganui Museum.

Corbula nitens n. sp. (Plate XIX, figs. 4, 7.)

Shell very small: height, 4 mm.; length, 7 mm.: subtrigonal. Valves not greatly unequal in size, but the right valve is considerably more convex than the left. Umbones of the two valves equal and incurved. Dorsal margin sloping. Anterior end distinctly the shorter, and rounded; posterior end rather the longer, and rostrate. Ventral margin gently rounded. Sculpture: Both valves with a rounded ridge extending from

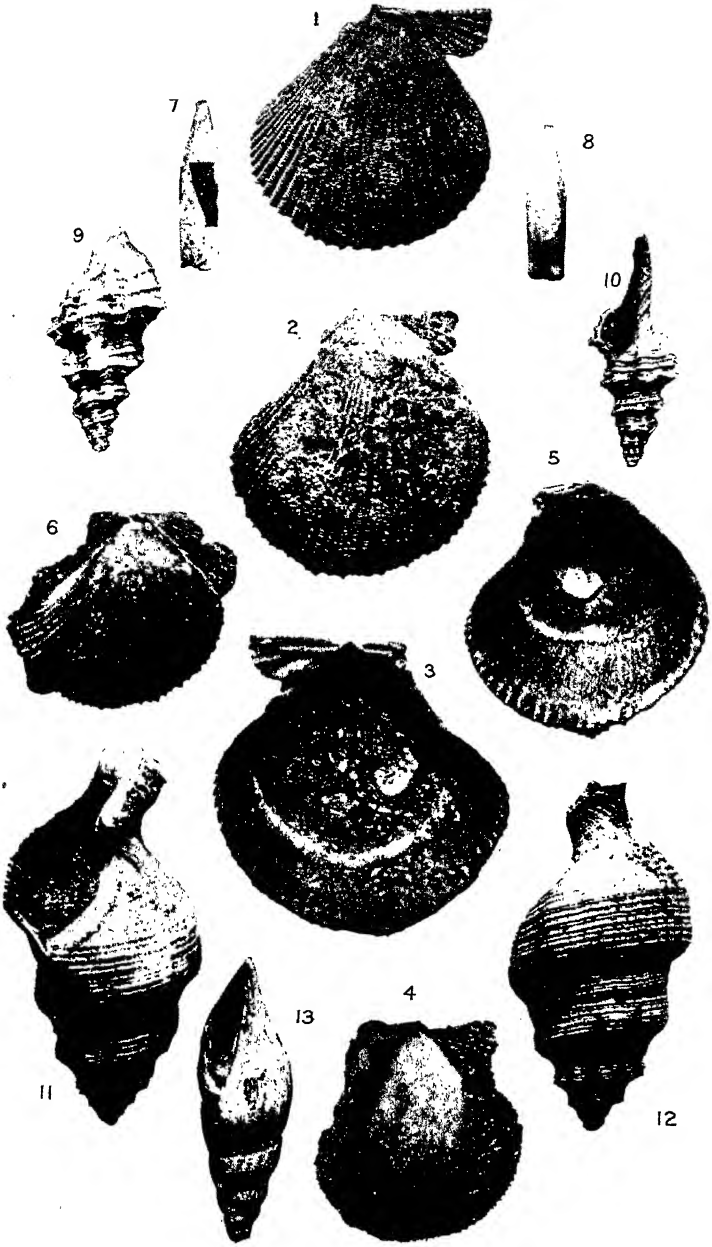


FIG. 1.—*Pecten costato-striatus* n. sp.
FIG. 2.—*Pecten costato-striatus* n. sp.
FIG. 3.—*Pecten costato-striatus* n. sp.
FIG. 4.—*Pecten subconvexus* n. sp.
FIG. 5.—*Pecten subconvexus* n. sp.
FIG. 6.—*Pecten subconvexus* n. sp.
FIG. 7.—*Vaginella torpedo* n. sp.
FIG. 8.—*Vaginella torpedo* n. sp.
FIG. 9.—*Fusinus corrugatus* n. sp.
FIG. 10.—*Fusinus corrugatus* n. sp.
FIG. 11.—*Siphonalia flexuosa* n. sp.
FIG. 12.—*Siphonalia flexuosa* n. sp.
FIG. 13.—*Coptochetus zelandicus* n. sp.

(All figs. × 2.)

the umbo to the posterior truncation: this is much sharper in the left valve than in the right. Near the umbo the right valve is smooth or has very small concentric striae. The concentric lines become more and more pronounced as the ventral margin is approached. The sculpture of the left valve is similar but somewhat less pronounced than that of the right. The outer coating of the shell is frequently absent, and then leaves a perfectly smooth and polished inner layer.

A common species at Pakaurangi Point. Type in the Wanganui Museum.

Pecten costato-striatus n. sp. (Plate XXII, figs. 1, 2, 3.)

Shell small, slightly inequilateral, fan-shaped: height, 17 mm.; breadth, 18 mm. Ears very unequal. Anterior ear large, nearly triangular, but with the outer margin rounded. It bears 7 radiating ribs crossed by a number of transverse bars, which are almost spiny. The radiating ribs which are near the hinge-line are much stronger than the others. Posterior ear much stronger, smaller, with 5 ribs less strongly crossed by transverse bars. Right valve with about 40 rounded radiating ribs, many of which subdivide into 3 each near the ventral margin. Each rib is crossed by a large number of transverse striations: these are so deep as to almost make the ribs appear to be composed of a large number of overlapping plates. Towards the ventral margin these may develop into small spiny processes. Interstices about as wide as the ribs, and crossed by a large number of fine transverse lines.

I am much indebted to Mr. Suter for examining this species, which he rightly remarks is closely related to *P. burnetti* Zittel. This species is perhaps the most abundant of the pectens at Pakaurangi Point. Type in the Wanganui Museum.

Pecten subconvexus n. sp. (Plate XXII, figs. 4, 5, 6.)

Shell small, fan-shaped: height, 16 mm.; breadth, 16 mm.: slightly inequilateral. Ventral margin nearly circular. Ears unequal, the anterior distinctly the larger with 6 radiating scaly ribs; posterior ear relatively small but with the same number of ribs, though they are less scaly and less prominent than those of the anterior rib. The shell has a large number of rounded radiating ribs. Intervening grooves usually much narrower than the ribs, and both the grooves and the ribs are marked by a large number of fine cross-lines. In some valves some 5 large radiating undulations can be distinguished.

Mr. Suter, who kindly examined these specimens for me, remarks that the species is near to *P. convexus* Q. & G. This species is fairly abundant at Pakaurangi Point. Type in the Wanganui Museum.

Including the species described above, the following is now the complete list of the species that I have found at Pakaurangi Point. Those marked * are Recent species.

Vaginella torpedo n. sp.
**Emarginula striatula* Q. & G.
Solariella stoliczkai Zittel.
Calliostoma gracilis n. sp.
Astraea subfimbriata Suter.
Turritella semiconcava Suter.
Struthiolaria cincta Hutton.
Cerithiella fidicula Suter.
Crepidula gregaria Sowerby.
**Calyptraea maculata* Linn.
Turbo etheridgei Ten.-Woods (?).
**Natica zelandica* Q. & G.
Polynices gibbosus Hutton.
Ampullina suturalis Hutton.
**Trivia avellanioides* McCoy.
Cymatium minimum Hutton.
Epitonium browni Zittel.
Epitonium trilineatum n. sp.

**Crossea labiata* Suter.
**Phalium achatinum pyrum* Lamk.
Galeodea senex Hutton.
Galeodea muricata Hector.
Galeodea sulcata Hutton.
Architectonica n. sp. (?).
Heliacus aucklandicus n. sp.
Fusinus kaiparaensis Suter.
Fusinus morgani Suter.
Fusinus corrugatus n. sp.
Dolicholatirus (*Pseudolatirus*) *ornatus* n. sp.
Ptychatractus pukeuriensis Suter.
Ptychatractus tenuiliratus Suter.
**Siphonalia dilatata* Q. & G.
Siphonalia flexuosa n. sp.
Coptochetus zelandicus n. sp.
Cominella carinata Hutton.
Phos kaiparaensis n. sp.
Phos spiralis n. sp.
Alectrion socialis Hutton.
**Murex angasi* Crosse.
**Murex zelandicus* Q. & G.
Murex zelandicus komiticus Suter.
Cymbiola corrugata Hutton.
Cymbiola nitens n. sp.
Cymbiola masefieldi n. sp.
Cymbiola calcar n. sp.
**Ancilla australis* Sowerby.
Ancilla papillata Tate.
Ancilla spinigera n. sp.
Ancilla cincta n. sp.
Marginella conica Harris.
Marginella harrisi Cossmann.
Surcula climacota Suter.
Surcula fusiformis Hutton.
Surcula latiaxialis n. sp.
Surcula nitens n. sp.
Surcula ordinaria n. sp.
Leucosyrinx alta transennus Suter.
Turris ornatus n. sp.
Turris kaiparaensis n. sp.
Drillia awamoaensis Hutton.
Drillia imperfecta Suter.
Drillia tenuispiralis n. sp.
Borsonia (*Cordieria*) *ovalis* n. sp.
Bathytoma haasti Hutton.
Bathytoma sulcata excavata Suter.
**Mangilia dictyota* Hutton.
Mangilia axialis n. sp.
Conus armoricus Suter.
Conus (*Leptoconus*) *lyratus* n sp.
Conus convexus n. sp.
Conus (*Lithoconus*) *abruptus* n. sp.
Terebra orycta Suter.
Acteon ovalis Hutton.
**Acteon craticulatus* Murdoch and Suter.
Crenilabium zelandicum n. sp.
Cylichnella enysi Hutton.
**Dentalium ecostatum* T. W. Kirk.
Dentalium pareorense Ihering.
Dentalium solidum Hutton.
**Cadulus delicatulus* Suter.
Leda semiteres Hutton.
**Leda fastidiosa* A. Adams.
Sarepta aucklandica n. sp.
Anomia poculifera n. sp.
**Arca novae-zelandiae* Smith.
Arca subvelata Suter.
Glycymeris subglobosus Suter.
Cucullaea alta Sowerby.
Cucullaea australis Hutton.
Mytilus torquatus n. sp.
Pecten beethami Hutton.
Pecten huttoni Park.
Pecten burnetti Zittel.
Pecten aldingensis Tate.
Pecten costato-striatus n. sp.
Pecten subconvexus n. sp.
Spondylus aucklandicus n. sp.
Lima colorata Hutton.
Ostraea wuellerstorfi Zittel.
Ostraea nelsoniana Zittel.
Ostraea tatei Suter.
**Cardita calyculata* Linn.
Venericardia subintermedia Suter.
**Thyasira flexuosa* Montague.
**Tellina eugenia* Suter.
**Tellina glabrella* Deshayes.
Tellina (*Areopagia*) *inconspicua* n. sp
Crassatellites attenuatus Hutton.
**Dosinia greyi* Zittel.
Dosinia tumida n. sp.
Macrocallista sculpturata n. sp.
Macrocallista assimilis Hutton.
Macrocallista pareoraensis Suter.
Cytherea chariessa Suter.
**Chione meridionalis* Sowerby.
Paphia curta Hutton.
Cardita (*Glans*) *kaiparaensis* n. sp.
**Cardium pulchellum* Gray.
Chama huttoni Hector.
Corbula canaliculata Hutton.
Corbula kaiparaensis Suter.
**Corbula macilenta* Hutton.
Corbula nitens n. sp.
**Panope zelandica* Q. & G.

This collection from Pakaurangi Point is of rather more than usual interest, as it is the first time that any attempt has been made to identify or describe a Tertiary fauna of such an extensive nature from any northern locality in New Zealand.

In the first place, there are several genera that have not previously been recorded from any locality in New Zealand. These are *Dolicholatirus*, *Coptochetus*, *Crenilabium*, *Spondylus*, *Sarepta*, and the subgenus *Cordieria* of *Borsonia*. On the other hand, *Acteon craticulatus*, *Cadulus delicatulus*, and *Crossea labiata*, all members of the Recent molluscan fauna of New Zealand, have not previously been found in the fossil state. The genera *Cymbiola* and *Surcula* are represented by more species than is usual in New Zealand fossil collections from Tertiary localities. The four species of *Conus* that have been collected give this genus a prominence that it fails to attain in any other collections from New Zealand localities.

A more general survey shows that in this collection of 124 species there are as many as forty-five, or 36·3 per cent., which have not been found elsewhere, while 20·3 per cent. are Recent species. Generically and specifically, therefore, this fauna is sufficiently distinct from any other that has been recorded. There are, however, no specially archaic types, while there are very many species identical with those that have been found in Tertiary localities in Canterbury and North Otago in those places where full collections have been made. This consideration, and the further fact that nearly 21 per cent. of the species are of Recent occurrence, shows that the age of the Pakaurangi beds is much the same as that of the beds at the North Otago localities of Wharekuri and Otiake—or, in other words, of the Oamaru limestone. In these localities the percentage of Recent species was found by Marshall to be 23·3 and 24 respectively, but in each case only some sixty species were collected.

In my previous papers insistence has been laid on the fallacy of relying too implicitly on the criterion of the percentage of the Recent species for the determination of the relative age of the Tertiary strata. The personal equation in connection with the identification of the species, the varying depth of the water, the geographical peculiarities of the station, are all matters that have to be taken into consideration before any comparison of real value can be instituted. In the present case, however, Mr. Suter has been good enough to examine and classify the species from both the Otago localities and from Pakaurangi Point: in consequence the personal equation in this comparison is of little importance. Similarly, the depth of the water in which deposition of the strata took place appears to have been of the same order of magnitude in both cases. Probably it was off-shore water in both cases approaching a depth of 100 fathoms.

The geographical features of the different localities may, however, have an important bearing on the question. The localities are nine degrees of latitude apart, and it is obvious that the species in the more northern locality should suggest a warmer climate than those in a locality more than six hundred miles farther south, in water relatively so shallow.

There is also a general belief that has been expressed by various authors that the climate of the New Zealand area has become relatively cooler since the early and middle Tertiary times. This opinion is based on the nature of the Tertiary Mollusca as compared with the Recent fauna, on the relatively large size of many of the Tertiary species, and of the greater variety of the species. Similar features have been noticed in regard to other animal groups. It is, of course, obvious that a general reduction of the temperature

within the New Zealand region would be more fatal to the northern species, which, owing to the limited extent of the land, would have no warmer littoral waters to which to migrate, than to the southern species, which would have a large extent of northern coast-line to which they could retire as the climate became cooler. This consideration supports the belief that the small percentage of Recent species in the Pakaurangi beds does not indicate a greater geological age than that of the beds at Wharekuri and of Otiake in North Otago. Actually, as explained in an earlier paper, these Pakaurangi beds succeed the white mudstones conformably, and these mudstones merge into the hydraulic limestones in their lower members. The hydraulic limestone is believed to rest conformably on the greensands, which in certain neighbouring localities contain an Upper Senonian fauna. This fauna includes the ammonoid genera *Kossmaticeras*, *Phylloceras*, *Lytoceras*, and *Baculites*, as well as the gasteropods *Amberleya*, *Cinulids*, and the lamellibranchs *Malletia*, *Panope*, and *Inoceramus*, amongst several others. It is hoped that this fauna, which has been found at Batley and at Bull's Point, both within a few miles of Pakaurangi Point, may be fully described in the next volume of the *Transactions*.

There are at Pahi, some five miles distant, some greensands lying beneath the "hydraulic limestones." In these sediments there are a large number of species of fossil Mollusca, but the shells are in a very poor state of preservation, and no attempt has been made of recent years to classify them. It is, however, the case that the species are mainly, if not entirely, of Cainozoic types, and the horizon is certainly lower than that of the Pakaurangi Point beds. Thus stratigraphically there is not any definite indication of the age of the Pakaurangi beds. There are certainly Upper Senonian beds at about 1,000 ft. below them, and the intervening strata are partly extremely fine mudstones and *Globigerina* oozes with much diatomaceous and radiolarian matter.

Palaeontologically also the exact age of the Pakaurangi beds is not precisely indicated. The percentage of Recent species does not give a satisfactory basis for a comparison with European horizons. The isolation of New Zealand and the relatively rare arrival of species from outside the New Zealand area make it probable that species would survive for a much longer time here than on coast-lines where there was more competition from newly arrived species. It is probable that a fauna in New Zealand with 20 per cent. of Recent species would have a much greater antiquity than a fauna with a similar percentage of Recent species in Europe or America.

The actual genera that have been collected do not appear to indicate any precise Tertiary age. *Exilia*, *Gilbertia*, and other genera from the lowest Tertiary beds of the South Island have not been collected here. *Fulgoraria* has not been found, and *Chione* is poorly represented. But such facts appear to depend upon station rather than age. Relative stratigraphical position with respect to beds deposited in water of similar depth in other parts of New Zealand would suggest an age rather younger than that of Wharekuri and Otiake, and such a position would generally agree with the palaeontological evidence. On the whole, I am inclined to correlate the beds with those of All Day Bay—that is, next above the Oamaru limestone.

As the work of collecting, classifying, and describing the Tertiary Mollusca gradually proceeds the number of species becomes much larger, and the fact emerges that there have been very few generic additions to

our fauna during Tertiary times. On the other hand, it is clear that many genera have become extinct. It is also the case that many of the genera that were in earlier times well represented have but few species in the present fauna. Those that have become extinct include *Cymbiola, Niso, Cypraea, Trivia, Conus, Latirus, Erato, Cerithium, Cardium, Exilia, Cucullaea.* More generally it may be said that of the 205 genera mentioned in Mr. Suter's *Hand-list of New Zealand Tertiary Mollusca* (1915) some forty-eight are now extinct. This statement, however, does not give a complete idea of the magnitude of the change that has taken place. Many of the genera that in Tertiary times contained a large number of species are now reduced to a very small number. Of these, *Epitonium, Surcula, Turris, Siphonalia, Struthiolaria, Mangilia, Pecten,* and *Polinices* are the most prominent examples.

In this comparison the purely littoral fauna cannot be properly considered, as remains of such organisms are so seldom preserved. No one Tertiary horizon which has had its Mollusca properly collected and described shows any notable introduction of species or genera which are absent from lower horizons. Such facts go far to support the idea of a continuous isolation of New Zealand throughout Tertiary times—a contention that has been previously urged by the author on purely stratigraphical grounds. This position has lately been supported by Thomson and Morgan, though stated in a different manner: "Each Tertiary fauna seems to merge gradually into the succeeding one."* Mr. Suter also has written to me as follows: "There is no doubt that our molluscan fauna has greatly decreased, and also that the Tertiary forms gradually merge into one another." These statements appear to me to afford the strongest support from the palaeontological standpoint to the view so frequently urged by me that there is no important break in the succession of Tertiary sediments in New Zealand. In the absence of satisfactory palaeontological material in the past this view has been based on stratigraphical material, and it is satisfactory to note that as the palaeontological material gradually accumulates its verity is placed practically beyond doubt.

It is to be hoped that a complete comparison may be possible ere long between our Tertiary faunas and those of Australia, South America, and North America. In the meantime one can only emphasize the well-known fact that our Tertiary fauna closely resembles that of South America, where the species of *Turritella, Malletia, Struthiolaria, Epitonium,* and *Polinices* are evidently extremely closely related to ours. Again, the occurrence of the genera *Perissolax* and *Heteroterma* in the Wangaloa beds shows a rather unexpected relationship between our earliest Tertiary beds and those of the Tejon and Martinez districts in California.

In New Zealand I have frequently stated that there does not appear to be any stratigraphical discordance between the Upper Cretaceous (Senonian) and the Tertiary horizons. In all known cases, however, deep-sea beds of *Globigerina* or diatomaceous or radiolarian ooze intervene between the Senonian and Tertiary horizons. In South America Wilckens, as previously pointed out, has insisted on an important break between the Senonian and the Miocene. Other authorities on the South American stratigraphy hold very different opinions. The latest that I have seen is that of von Ihering, who maintains emphatically that there is no break between the Cretaceous and Tertiary: "Überblicken wir die von uns

* Preface to *Palaeontological Bulletin No. 5,* 1917.

gewonnenen Ergebnisse, so muss jede unbefangene Diskussion die Tatsache anerkennen: dass die marinen Ablagerungen der oberen Kreide von Patagonien eine starke, successive Abnahme von mesozoischen Charakterformen aufweisen, dass aber andererseits diese letzteren sich zum Teil erhalten, dass mithin die Elemente der Kreidefauna teils unverandert, teils modifiziert in die patagonische Formation übertreten und dass keine Discordanz zwischen der Kreide und den Ablagerungen der patagonischen Formation besteht."*

So far as New Zealand is concerned, then, it appears to be probable that at the close of Cretaceous times a great movement of epeirogenic depression took place. The land area was reduced to the dimensions of a few small islands. Over much of the present land area deep-sea oozes were deposited for a great lapse of time. Marginal deposits were restricted and small. When elevation again commenced the Upper Cretaceous fauna had been replaced by one of Tertiary characteristics.

Art. XXVIII. — *Notes on the Geology of the Tubuai Islands and of Pitcairn.*

By P. Marshall, M.A., D.Sc.

[*Read before the Wanganui Philosophical Society, 19th December, 1917; received by Editors, 31st December, 1917; issued separately, 24th June, 1918.*]

The scattered islands which constitute the Tubuai Group are situated near 23° south latitude and 150° west longitude. Little geological information has been published about them except in regard to their general configuration and the nature of the coral reefs by which they are encircled.

A visit has lately been made to the group by Professor J. Macmillan Brown in connection with his anthropological studies, and he has been good enough to give me chips from implements that he obtained from Tubuai and Rapa. In addition, the Chief Magistrate of Pitcairn sent me several specimens from that island. I have previously published a note on rock-specimens from Rurutu Island, another member of the Tubuai Group.†

Stone Axe, Tubuai Island.—A dense black rock in hand-specimens. In section the structure is dominated by an abundance of small laths of feldspar with the extinction angle of labradorite. There are a few large crystals of olivine much serpentinized. There is also a little olivine in the groundmass. Augite is very plentiful in the groundmass in small colourless grains. Magnetite very abundant. The rock must be classed as a dense, rather acid basalt.

Stone Axe, Rapa Island.—In hand-specimens a dark fine-grained rock without any crystals that can be distinguished macroscopically. In section fine laths of feldspar are very abundant. They appear to be an acid labradorite or andesine. Augite is very plentiful, but the grains seldom have any crystalline outline, and they are quite colourless. A little olivine is present in very irregular-shaped grains. Magnetite is very plentiful in crystals up to 0·2 cm. in diameter. A little apatite can be distinguished. This rock is also an acid feldspathic basalt, and, like the specimen from Tubuai, it has an unusual quantity of magnetite.

* Von Ihering, *Revista do Museu Paulista*, vol. 1, Fasc. 3, p. 130 Sao Paulo, 1914.
† *Trans. N.Z. Inst.*, vol. 46, p. 283, 1914.

Poe Pounder, from Rapa Island.—In hand-specimens a coarse rock in which feldspar, augite, and olivine can be easily distinguished. In section the feldspar is found to have occasionally a large angle of extinction—as much as 40°—and thus is a basic type of labradorite. The great majority of the crystals, however, have very narrow lamellae, and extinguish at angles below 20°. The species apparently varies from andesine to basic labradorite, which is confirmed by the low index of refraction. Augite is present in large ophitic plates with the pleochroism that is so common in the titaniferous varieties. Olivine is present in large irregular grains slightly serpentinized, and it is often associated with minute flakes of brown mica. Iron-ore is abundant. It is mainly ilmenite, as shown by the shape of the crystals and by the frequent border of leucoxene. There is much apatite, especially as inclusions in the plates of augite.

I have lately received from Mr. G. R. B. Christian, the Chief Magistrate of Pitcairn, a box of rock-specimens from that remote spot. He states that the specimens sent represent the various kinds of rock that are to be found on the island so far as can be judged by external appearance. My only previous reference to rocks of this island is a statement that a specimen given to me by Mr. G. W. Card was a glassy hypersthene andesite.* The rock-specimens that I have now received cause me to correct the previous classification. I now recognize the rock as a glassy basalt. In the specimen previously examined only one small crystal could be seen. It was thought to be hypersthene, but subsequent specimens now show that it was olivine stained slightly with iron oxide. The more numerous specimens that I now have are all fine basalts, many of which are glassy. The feldspar is an acid labradorite. Olivine, usually in idiomorphic crystals, is usually more plentiful than the colourless augite, which is always granular. The fineness and frequently glassy nature of the rocks suggest that they have a submarine origin. So far as these rock-specimens are concerned, they indicate that on several of the islands of the Tubuai Group a similar rock type occurs. Tubuai, Rapa, Rurutu, and Pitcairn at least have highly feldspathic basalts. In general all of the rock-specimens that I have examined are so similar that they all might have occurred on the same island. The specimens from Tubuai and Rapa are types that have been selected by the natives for the manufacture of weapons, and hence they may possibly be unusual types on the islands, selected because of their special fineness or toughness. The specimens from Rurutu and Pitcairn, however, appear to be typical of the rock occurrences on those islands. Generally it may be said that the rocks of the Tubuai Group appear to be less basic than those of Tahiti and the Cook Islands, and the specimens so far examined show none of the alkaline characters found in many of the rocks from those groups.

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* *Handbuch der regionalen Geologie*, Bd. vii, Abt. 2, p. 14, 1912. MICHEL LEVY (Examination petrographique de quelques roches volcaniques des îles Tuamotu et de l'île Pitcairn, *C. R. Acad. Sci. de Paris*, cxli, p. 895–97, 1905) writes as follows: "En résumé il existe à Pitcairn et à Mangareva deux séries de roches basaltiques: une plus acide de basaltes andesitiques passant à des andesites à olivine et à des tachylites (Pitcairn): une autre plus basique composée de basaltes labradoriques quelquefois très augitique d'autrefois très riche en olivine du premier temps: cette dernière paraît être la plus frequente. Il faut voter en outre l'existence à l'île Pitcairn de ponces trachitiques presque entièrement vitreuses et par suite peu interessantes au pointe de vue minéralogique." The more basic type mentioned by Michel Levy was not represented in my specimens.

Art. XXIX.—*A Note on East Coast Earthquakes (N.Z.), 1914–17.*

By George Hogben, C.M.G., M.A., F.G.S.

[*Read before the Wellington Philosophical Society, 12th December, 1917; received by Editors, 31st December, 1917; issued separately, 24th June, 1918.*]

Between February, 1914, and November, 1917, about thirty earthquakes (not counting shocks of intensity I or II, Rossi-Forel) were recorded at places on or near the east coast of New Zealand. The chief of these were the earthquakes of 6th–7th October, 1914; 28th October, 1914; 22nd November, 1914; and 5th–6th August, 1917. All the shocks came from a region to which in a former paper* I have referred the earthquakes of 9th August, 1904; 9th March, 1890; and 17th February, 1863.

The most marked effects of the first three earthquakes (October and November, 1914) appear to have been noted at Tokomaru and other places a little to the south and south-west of East Cape; but they were sharply felt from Timaru and Greymouth to Auckland. Their intensity was sufficient to throw down chimneys in the Tokomaru district, and to stop some clocks in Wellington and other places.

The movements originating the vibrations appear to have taken place in each of these cases beneath the sea-bed, probably both at the north-east and south-west ends of the three lines *Aa*, *Bb*, *Cc*, beginning at the north-east point, *A*, *B*, or *C*, and ending at the south-west point, *a*, *b*, or *c*; suggesting the existence of three fault-planes whose position is shown by the lines on the map. These conclusions rest on the instrumental records from Wellington and Christchurch (Milne seismographs), and from Apia, Riverview (Sydney), and Batavia (Wiechert instruments), and a large number of memoranda from telegraph officers in New Zealand, forwarded to me by the courtesy of the New Zealand Post and Telegraph Department—which it would take too long to discuss here. (It is quite possible that better records would have made the three lines *Aa*, *Bb*, and *Cc* coincide.)

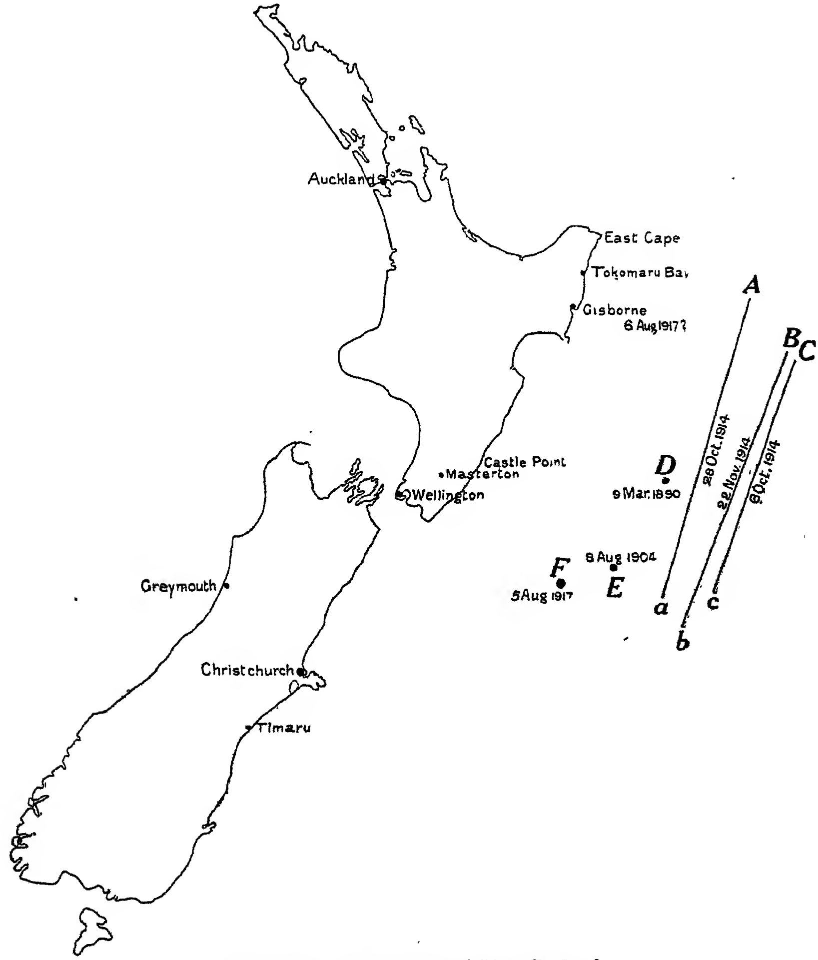
A fact worth noting is that the Milne seismograms of the 6th October at Christchurch and Wellington both showed a considerable tilt of the ground down on the eastern side (7 mm. at Wellington, 5·4 mm. at Christchurch, or 2·28 and 1·76 seconds of arc respectively). This might have been attributed to instrumental causes were it not that a Milne-Ewing duplex pendulum at Wellington, set up on an independent column about 9 ft. from the column on which the Milne seismograph was placed, showed a tilt of corresponding amount nearly towards the south-east. (The needle of the duplex pendulum is, of course, free to move in any direction horizontally, whereas the Milne seismograph records only the E.–W. component of the motion.)

The earthquake of the 5th–6th August, 1917, was most severely felt in the district between Masterton and Castle Point, especially at the former place†—probably because of the alluvial character of the ground on which the town is built. The epicentral area is near *F*, in lat. 42° 41′ S., long. 178° 12′ E., which is not far from the origin of the earthquake of

* G. Hogben, Notes on the East Coast Earthquake of 9th August, 1904, *Trans. N.Z. Inst.*, vol. 37, pp. 421–24, 1905.

† Probably the intensity at Masterton may be described as between VII and VIII on the Rossi-Forel scale.

8th August, 1904. A day later (6th–7th August, 1917) a sharp shock, though not so severe, was felt in the region from Gisborne to the East Cape, evidently from the east or east-south-east. It is quite possible that the latter was from the north-east end of a fault-line of which *F* marks the south-west end. *F* is about 185 miles from Wellington, and 285 miles from Christchurch.



Earthquake origins east of New Zealand.

The times relied upon for the determination of *F* were those of the first phase ("preliminary tremors") at Apia, Samoa, 15 h. 56 m. 27 s. (*Wiechert*); Riverview, Sydney, 15 h. 55 m. 11 s. (*Wiechert*); Christchurch, N.Z., 15 h. 51 m. 24 s. (*Milne*); Wellington, N.Z., 15 h. 51 m. 6 s. These, with a velocity of propagation of 9·17 km. sec., show the time at the origin to have been 15 h. 50 m. 34 s., G.M.C.T., 5th August, 1917 (3 h. 20 m. 34 s., N.Z.M.T., 6th August). The respective distances of the four places named from *F* are: Apia, 3,235 km. (chord); Riverview, 2,538 km. (chord); Christchurch, 456 km.; Wellington, 296 km.

The times and other observations forwarded from New Zealand telegraph-offices, while less exact, afforded a general confirmation of the result obtained from the instrumental observations.

Art. XXX.—*Further Notes on New Zealand Bird-song: Kapiti Island.*

By Johannes C. Andersen.

[*Read before the Wellington Philosophical Society, 24th October, 1917; received by Editors, 31st December, 1917; issued separately, 24th June, 1918.*]

The figures accompanying this article contain the new notes observed since publication of the paper in the *Transactions* of 1917.* As before, for convenience of reference, the variations in the notes of each species of bird have been numbered consecutively from (1) onwards, the earlier numbers appearing in *Trans. N.Z. Inst.*, vol. 41, p. 422; vol. 43, p. 656; vol. 45, p. 387; vol. 47, p. 593; vol. 49, p. 519. Reference is at times made to these earlier-numbered variations. As practically the whole of the notes were recorded on Kapiti, the island bird sanctuary in Cook Strait, it has been thought advisable to prefix a list of the birds occurring on the island, and seen or heard by me:—

Native Birds.

Pied fantail (piwakawaka), *Rhipidura flabellifera.*
*Grey warbler (riroriro), *Pseudogerygone igata.*
White-breasted tit (miromiro), *Petroeca toitoi.*
North Island robin (toutouwai), *Miro australis.*
Whitehead (pokotea), *Certhiparus albicapillus.*
Ground-lark (pihoihoi), *Anthus novae-zealandiae.*
*Blight-bird (tauhou), *Zosterops caerulescens.*
Tui, *Prosthemadera novae-zealandiae.*
Bell-bird (korimako), *Anthornis melanura.*
Rifleman (titipounamu), *Acanthidositta chloris.*
*Shining cuckoo (pipiwharauroa), *Chalcococcyx lucidus.*
Long-tailed cuckoo (koekoea), *Urodynamis taitensis.*
Kingfisher (kotare), *Halcyon vagans.*
Pigeon (kukupa), *Hemiphaga novae-zealandiae.*
Kaka, *Nestor meridionalis.*
Red-fronted parrakeet (kakariki), *Cyanorhamphus novae-zealandiae.*
†Antipodes Island parrakeet, *Cyanorhamphus unicolor.*
Morepork (ruru), *Ninox novae-zealandiae.*
Woodhen (weka), *Ocydromus* sp.
†Kiwi, *Apteryx* sp.
Blue heron (matuku), *Demiegretta sacra.*
Blue petrel, *Halobaena caerulea.*
Mutton-bird (titi), *Oestrelata* sp.
Gannet (takapu), *Sula serrator.*
Tern (tara), *Sterna* sp.
Gull (karoro), *Larus* sp.

Introduced Birds.

Song-thrush, *Turdus musicus.*
Skylark, *Alauda arvensis.*
Goldfinch, *Carduelis elegans.*
Starling, *Sturnus vulgaris.*
Californian quail, *Callipepla californica.*

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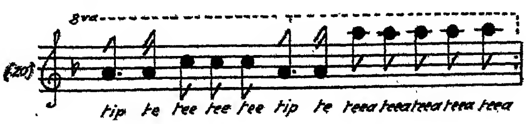
* *Trans. N.Z. Inst.*, vol. 49, pp. 519–30.

The birds marked * I neither saw nor heard, but I was assured by the caretaker, Mr. J. L. Bennett, to whom I am deeply indebted for consideration shown to me whilst on the island, and by Mr. Webber, who resides at the north end of the island, that they are plentiful at times. The two marked † have been introduced, and appear to have established themselves. A longer residence on the island—I was there three weeks—would probably show a large increase in the number of sea-birds; and the lagoon in the north is visited by ducks, but I saw none whilst there. I saw no live thrush, but found one dead and heard one sing. Goldfinches suddenly appeared, in flocks. Skylarks were there in numbers, and starlings also. On the evening of the 2nd January, 1917, lying on the hillside, my attention was attracted by a moving cloud above Evans Islet*—a small islet off the coast of Kapiti, and lying between it and the mainland. The cloud vanished, and formed, and vanished, like a cloud high in the blue sky of summer, only with swifter transitions. It was a flight of starlings, many hundreds in number, and the cloud formed by the crowded birds appeared and disappeared according as they presented an edge or full body as they flew. The unanimity of movement must have been perfect to cause the regular melting and reappearing of the cloud. The birds gather from many quarters on the mainland, and every evening fly in thousands to Evans Islet, passing the night there, and leaving again, flock by flock, in the morning. A similar habit is observed in Britain, but I have seen no note of such nightly haunt, or starlingery, being divided by the sea from their daily resort. Evans Islet is over two miles from the mainland, and is uninhabited and unoccupied. There is another starlingery on the mainland in a plantation of blue-gums close to Paraparaumu, between it and the sea; and at sunset there is a great clamour of twittering before the birds settle down for the night. I am told that the birds visit Evans Islet nightly during the breeding season also, but not in such great numbers. I was surprised to see not a single sparrow; but it is quite possible that this bird, and the other finches, may pay occasional visits: they have, indeed, been reported there at various times.

FANTAIL.

I did not see a great number of fantails at Kapiti, but all that I did see were pied. Their song was generally the common whistling song, (15) and (15A), heard about Wellington. The notes of (20) were heard on the



10th January, 1917, the phrase being repeated twice or oftener each time it was sung. The high notes may be slurred downwards slightly in the change of vocalization from *ee* to *a* in *teea*, the sound of which was almost *dear dear dear.*

WHITE-BREASTED TIT.

When I heard the first song I did not see the bird, but the sound was the same as that of the yellow-breasted tit's little plaintive warble. On

* Maori name, Tokumapuna; known locally as Toku.

this occasion it was vocalized *ri-di-dl, ri-dl, ri-dl* (short "*i*" as in "pit"), and it was sung at about eight quavers in a second. There was a very short grace note before the first E, and traces of it at times before the

others. The phrase was sung two or three times with two or three seconds' pause between the repetitions. Nine days later I saw the bird singing (2), which in sound was nearer a whistle, but gave very faint traces of the same vocalization as (1).

North Island Robin.

I saw a robin singing the first day I was on Kapiti. It was in a shady, watered gully close on the beach, and he sat singing a few feet distant—a gentle, bright warble, not so cheery as that of the whitehead, nor so shrill, but more varied and longer continued. I was not yet armed with paper and whistle, so was unable to take any notes, nor did I attempt anything but enjoy the song, thinking I should hear him often enough, since he greeted me thus on the first day. In this I was disappointed; and I have found that in these observations unless a record is noted down at once it is probably never noted.

On the 12th January, 1917, as I was climbing a bush-grown spur, a robin appeared in the midst of a manuka thicket, and on my sitting down it approached until within a foot of my side. After a time it uttered a very subdued sound like *che-e-er*, almost like the muffled mewing of a kitten. It was apparently a young bird, for presently another approached and quickly popped a cricket into its bill. As the second bird approached, the first *che-e-er*-ed louder and more continuously, and fluttered with its wings; then both went off together. The young bird was as big as the parent, and both appeared the same in colour—almost black on the back, grey on the belly, darker grey on the breast; and it was noticeable that the dark

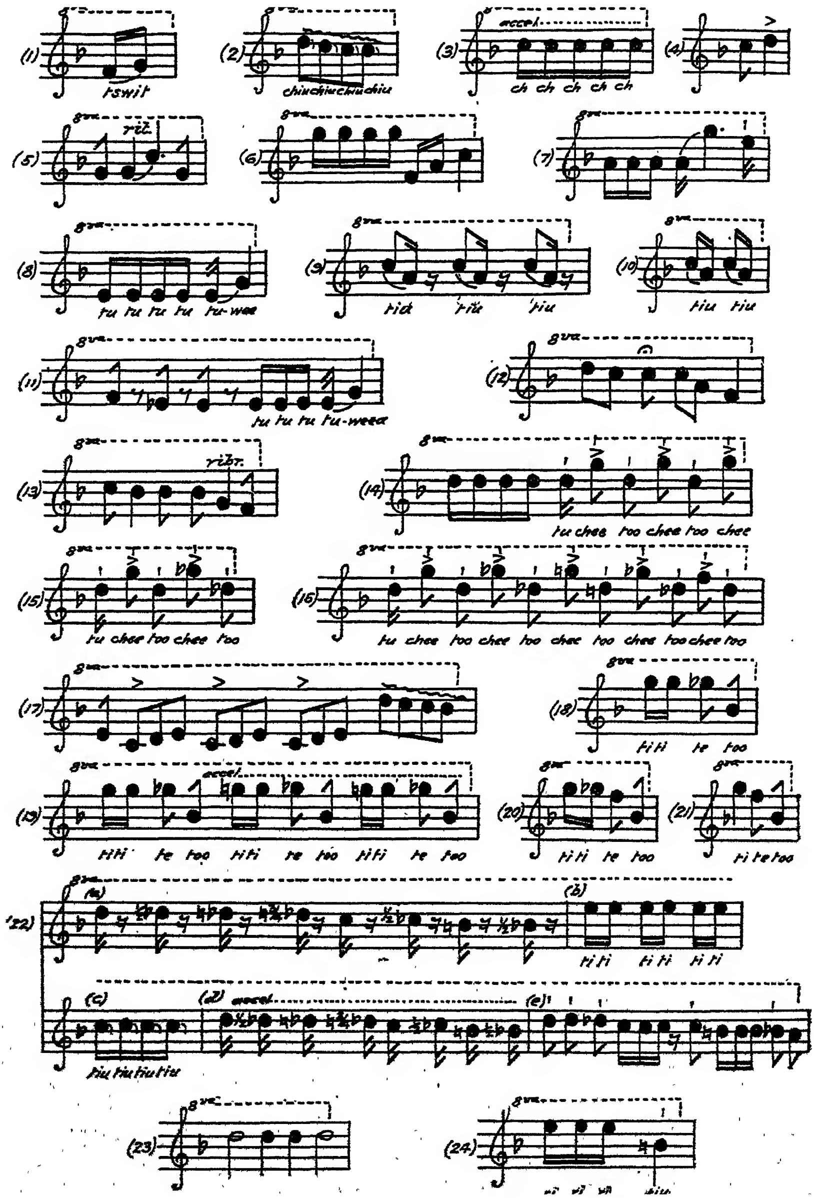
hues of the back, head, and breast were marked with discontinuous longitudinal streaks of light grey, as if the body-plumage were grey, like the belly, and overlaid with the darker shades. I heard more *che-e-er*-ing close by in another direction, so other young ones were evidently being fed. I saw a goodly number of young during the day—three at one time.

The call-notes (1), heard several times, were clear, sharp whistles, uttered at the rate of six or seven semiquavers or their equivalent a second; they are the same in quality as those of the South Island. A song was begun on the 12th January, 1917, but got no further than (2). Three days later, in the bush above the mid-valley of Taepiro, a robin immediately overhead broke into the song of (3), repeating the single phrase, usually as in (3A), but adding nothing more. The second note of the triplet was very faintly uttered, as if it were not quite a separate note, but a "catch," and at a distance the sound of the phrase was simply *ti tee-oo* or *ti ti tee-oo* (short "*i*" as in "pit"). It was a sharp plaintive whistle, the plaintiveness coming in the slur. The robin went, whistling now and again from a receding distance, when suddenly a whitehead settled near by, and in sight and hearing whistled (4). The opening notes are its own; the close is an exact reproduction of the robin's phrase, save for the curious soft final echoing of the slur. I have heard many instances of apparent imitation by many birds, but this was the first occasion where the imitation was so palpable that it might be recorded as indubitable.

WHITEHEAD.

The commonest bird on the island, and the noisiest, was the whitehead: he was always to be seen and heard, in all places and at all times of the day. He is one of the optimists of the bush, finding pleasure everywhere, and never scrupling to make the fact known. His most frequent cry was a quick slurred note, as in (1), vocalized *tswit.* This was uttered almost incessantly as the bird searched for insects. He would pause occasionally, stand erect, with head elevated, beak open, tail vibrating, and cry "All's well with the world," uttering the notes of (2) to (6), all of which, apparently, are calls that call for no reply, or replies to calls which may or may not have been given. At times one or other of these was uttered alone; at times in various combinations, two or three being connected, apparently at random. The notes of (2) varied from four to ten in number, descending enharmonically through from two to four semitones. The combinations most commonly used were (2) followed by (3) or (4), or (3) followed by (4). Less commonly (5) entered into the combination. The run (2) was very frequently sung, the small steps in the pitch being quite distinct; the vocalization *chiu chiu*, too, caused the notes to sound as if slurred downwards slightly in every case. The notes of (3), sung much faster, lost all trace of the slur, their vocalization, too, being *ch ch ch* instead of *chiu chiu chiu.* The notes of (4), an octave lower in pitch, were clear, mellow whistles, almost flute-like, quite different from the characteristic warble notes of (2) and (3): it was as though another bird concluded with (4) on the whitehead opening with (2); but the bird was seen many times whilst singing the two parts combined. One was heard warbling (2) (3), another answering with (2) alone. The notes of (2) were, in quality and fall, almost like the note of the chaffinch. When the combination (2) (3) (5) was sung, the result was rather plaintive, owing to the slurred crotchets at the close: usually the call-notes were loud, bright, vigorous, and cheerful. The combined call (2) (3) was uttered in about a second and a half.

It has been objected that the tempo of the notes is indicated in a roundabout way by saying "so-many in a second," and that the musical terms existing for indicating tempo should be used. But the musical terms are



altogether too indefinite: neither *Lento* nor *Presto* say exactly how slowly or how fast the tempo is intended. The only definite indication in music that will give the exact tempo is M.M. ♩ = 120, which signifies that on

Maelzel's metronome 120 crotchets are beaten in one minute. This would mean two crotchets in a second, or four quavers, so that the combination (2) (3) referred to, containing, say, six quavers uttered in a second and a half, is practically in the tempo M.M. ♩ = 120. It must be remarked that the tempo of the whitehead's song varied exceedingly, from about five to ten quavers a second—and that, too, within very short intervals of time. The bird would appear to become momentarily excited, when the notes increased both in tempo and in loudness. The combination (3) (4) might be varied as (6), where again the low notes were clear whistles. The slur entered into other calls, as in (7). This might be sung, at intervals, many times in succession, the time occupied being a second and a half: at times there was a vibrato on the slur. The slur of (8) was at times preceded by fuller and slower whistles as in (11), notes richer and more deliberate than the ordinary impatient warble notes. The time taken by (11) was from a second and a half to two seconds: the opening notes were sometimes sung alone, the E flat varying one to three in number. The half-song (8) was also, at times, followed by higher down-slurs (9) and (10), sometimes one, sometimes both, and (8) might then be repeated. The full phrase (11) (9) (10) (9) (8), or like combination, formed the rudiments of an agreeable song. The number of semiquavers in (8) and (11) was quite indefinite. The notes of (12) and (13) made up phrases well suited for song-building: the lower notes, as usual, were fuller and richer than the higher, and (13) had a plaintive close. The notes B G were not slurred, though they seemed connected in the phrasing, as though an intended slur were broken by a momentary closure, keeping both notes pure. There was a faint vibrato present, occasionally, on the G. The notes of (14) to (16) were clear whistles, varying in number from three pairs upwards, about four quavers a second. They were almost staccato, and were not always clear, being at times vocalized as in (14), when it sounded as though the bird had a stone in its mouth. The first short note was vocalized *tu* (short "*u*" as in "but"). There was a curious and irregular variation in this phrase: it might open as in (14), or the first four notes might be omitted; at times the last D was D flat, or the last two notes might be flat, as in (15), or there might be a succession of flat and natural pairs as in (16). These semitone variations were evidently under control, as the bird appeared to sing one or other at will, and whichever was sung was clear and unhesitating. The phrase (14) was reminiscent of the fantail's common song, and (17) of a less common song by the same bird: the triplets, a clear rapid whistle, were followed by the common enharmonic notes of (2). The phrase (18) was sung for several minutes continuously, either singly at intervals, or repeated twice, three times, or more. If three times, as in (19), a rapidly developed accelerato took place, from about six to ten or more quavers a second. In the vocalization the "*i*" and "*e*" were short. The sequence was varied as in (20) and (21).

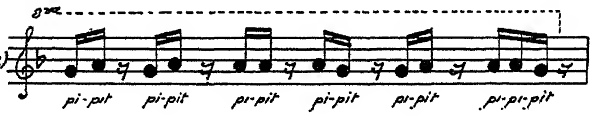
Whilst the usual notes of the whitehead were simply phrases such as the foregoing, repeated either singly or in various combinations, it had also a true song—that is, a continuous strain, built up of various phrases combined so as not to be mere repetition. A portion of such a song is shown in (22). The phrases (*b*) and (*c*) entered into it largely, and these gave to the song its canary-like character. The phrase (*d*) is (*a*) repeated without rests, and with an accelerato running through it. Some of the notes were whistles, some warbles; those of (*c*) had the sound of being slurred.

The cry of (23) was probably that of a young bird: the note was vibrato, at first slow, in semiquavers, then rapidly faster until it throbbed like a cricket's *chirr*, and broken as indicated. The notes of (24), heard occasionally following (2), were very like the cry of the parrakeet. They were uttered alone at times, lasting half a second. The whitehead almost certainly imitates the robin; it is possible, in view of (14) and (17), that he imitates the fantail, and in view of (24) the parrakeet. His deeper notes, too, are often like those of the bell-bird, with which he at times associates. Again, it is possibly not mimicry at all, but a chance resemblance of a few of the notes to the notes of other birds.

Ground-lark.

There is a fair number of ground-larks on the open flats at Kapiti. I did not hear its song; but its call, during flight, is as in (2). These

(2)



couples or threes are uttered in irregular sequence, and at irregular intervals.

Tui.

The tui is very plentiful on Kapiti, and very tame. The call of (92) with its many variations—(92A) to (92J)—took the place of the five-bell call of the South. The repeated semiquavers varied from two to four, more often two or three, sung at the rate of about ten a second, the effect being the same as that of the rebounds of a hammer on an anvil. The commonest forms were (D) and (E), with three semiquavers; these were sung more or less every day. The variation (C), was uttered in about a second and a half at intervals of from fifteen to thirty seconds, the first note being strongly vocalized; in the whole of the variations, too, the first note was vocalized more or less. Variations (A) and (B) were sung at 3 o'clock in the morning, the difference in pitch being unvarying. Whether the notes were by one or two birds it was impossible to say; they came apparently from the same quarter, and as they were calls before the morning chorus, in which several birds took part, they were possibly by two birds. The notes of (F) were sung in the air. The tui flew up, closed its wings, and dived perpendicularly from a height of 20–25 ft. into a karaka, spreading the wings and tail at the moment of entering the foliage. The notes were sung during the fall; time, under two seconds. The *tsrr tsrr* was almost a squeak, and the F was faintly vocalized *kiau;* the "*i*" of the G was short as in "pit"; the notes on B were in full flute tones. The opening notes were rarely downwards as in (G). At times the rebound quickened to a vibrato, as in (H) to (J). The vibrato, on the first part of the note only, was very light, though distinct. On the 25th December, 1916, a tui in the distance, at evening, sang (93). Occasionally he sang the three consecutive notes of (A), but more often he sang the notes singly, sometimes one, sometimes another, at intervals—about three in two seconds. At times he sang (B), more rarely (C)—all clear, flute-bell tones. (93D) was sung on the 2nd January, 1917, and in it the notes of a minor chord occur—an unusual

chord in the bird-world: it was sung several times, the value of two crotchets in a second. In (93F) occur the notes of an ordinary major chord; this, and (93E), were sung in the afternoon of the 3rd January. (93G) was in subdued, mellow, bell tones, the value of 3–4 crotchets a second. More sound may have followed, but no more was heard, and the bird was unseen. It is often impossible to say whether the notes of an unseen bird are sung by a tui or a bell-bird, they have so many in common; but the bell-bird's notes are chiefly characterized by their rapid speed of utterance, corresponding with the restless movements of the bird. On hearing the notes (93G) I unconsciously expected a fourth note, a D—and I suddenly became conscious that the first four notes were those of the

opening of "Scenes that are Brightest." This led me to hark back in memory to see if I could recollect other bird-phrases that recalled human melodies, but only one came to mind, a phrase by a bell-bird—B flat, B flat, E flat, G, B flat, E flat, B flat, G—which, with the addition of E flat, F, is the second line of "Mill May": "The bob-o'-link sings on the tree." So far from its being remarkable that bird-phrases should sometimes be the same as human melodies, it is to me remarkable that they are not more often the same.

The notes of (94), heard only occasionally, are reminiscent of calls in the South. The opening sounds, at three quavers a second, were like the sound of a bell through the horn of a gramophone; they were followed by the common call at a higher pitch. In (95), again, the notes of the chord are sounded. It was sung once only, after flight, and after a second flight the variation (95A). The notes were full flute notes, with regular vocalization, *aw* in the low notes, *e* of "net" in the medium, and *ee* of "sweet"

(97)

(98)

(99)

(100)

(101)

in the high notes. The jews'-harp sound *tanga* or *tanga-a-wang* blended with perfect smoothness. There was a slight accent on the second note and on the dotted crotchet, and the whole phrase was sung in about two seconds. In (96) a whisper-song was broken into by the ordinary call, which was more reedy than bell-like, and might be reproduced on a clarionet. The whisper-song was nearer a warble than whistle or flute tone. The bird

sang whilst a gale of wind swayed the branches of the karaka in which he sat. The theme was varied by varying the position of the parts, as (*c*) (*c*) (*a*) (*b*) (*c*) (*c*) (*c*) (*b*) (*c*) (*a*) (*c*) (*b*), &c. The tempo was about eight semiquavers a second. The short phrase (97) was sung in the evening, softly, like the whisper-song. The first notes were vocalized *sweet;* the others were clear whistles, with a sound of *tee-ee tee-ee,* and resembled the fantail's whistling song. A violin-string might reproduce the tone if it could be muted sufficiently.

I was out several times to hear the morning chorus, which would begin at about 3 o'clock, whilst still quite dark, with the common call, repeated at intervals independently by two or more birds. After ten minutes or so a bird would begin the beating theme of (98), varied as in (98, *b*). In the latter the place of the rest was at times taken by a note, making the beating continuous. Others joined in, the sound being half bell, half flute; and though several birds sang, as could be heard owing to different birds dropping to E at different times, and also varying to B at different times, the result was quite harmonious. The common call continued to be uttered at intervals.

The harmony was fuller on the 2nd January, 1917, when the call was (92A) and (92B). The call sounded (A) (A), pause; (A) (A) (B), pause; (A) (B), pause; (B) never opening a call. When other birds joined in, the theme (98) began, but the notes were G, D. There were at least two birds singing the notes, as the D was at times accompanied by a *tiu;* and, whilst the notes of G were usually sounded together, at times there was an interval between as though one bird lagged a little. At the same time another bird sang C, in a thinner tone, more than an octave above the rich bell tones of the others. The effect was as in (99). The top singer was occasionally slightly out of time also. The theme was, on the 4th, varied as in (100). This was very beautiful, though apparently two birds only were singing, a third making a sort of bass accompaniment with an occasionally interjected *tiu tiu.* The fact that the higher singer was more than an octave above the lower was especially noticeable when the C was touched by both birds. Whilst a great number of birds may be singing at the one time, they would appear to segregate into small parties or choirs of from three to five, the song of each choir being in time and tune, whilst not always harmonizing with the others. With the whole bush full of singing birds, any segregation there may be would be lost. At dawn the small birds joined in the chorus: I heard whiteheads and fantails, whilst out above the flats sang an English skylark. Their songs did not harmonize with the rich notes of the larger birds, but the wild chorus resulting was most pleasing. It was impossible to say if the singers were tuis or bell-birds, or both; but the choruses are noted in this place as they began with tui calls, and the calls continued to be heard, at least for a time, during the singing of the chorus. One of the birds taking part, a tui, was seen in a karaka, though his attention seemed more devoted to the ripening berries than to the chorus. In (101) there were four or five birds singing, small birds again joining in towards the close. The parts of the principal singers, parts 1 and 2, were very regular and long-continued: 1 began, and, after a minute or two, 2 joined in, and these two continued for a quarter of an hour or more. A few minutes after 2 had joined 1, 3 joined in, singing irregularly and intermittently; still later and more intermittent was 4, almost a whisper-song. The call, as in 5, sounded occasionally. The chorus was, for the most part, quite harmonious and in perfect time:

occasional discords sounded, but they were not unmusical; the singers sang sharp or flat, or lost time, but soon recovered both tune and time. The two principal parts showed a great variety of themes: on the 10th and 15th January they were as in (102), and on the 13th as in (103)—a most beautiful theme. In this the upper notes sounded very high in pitch,

(102)

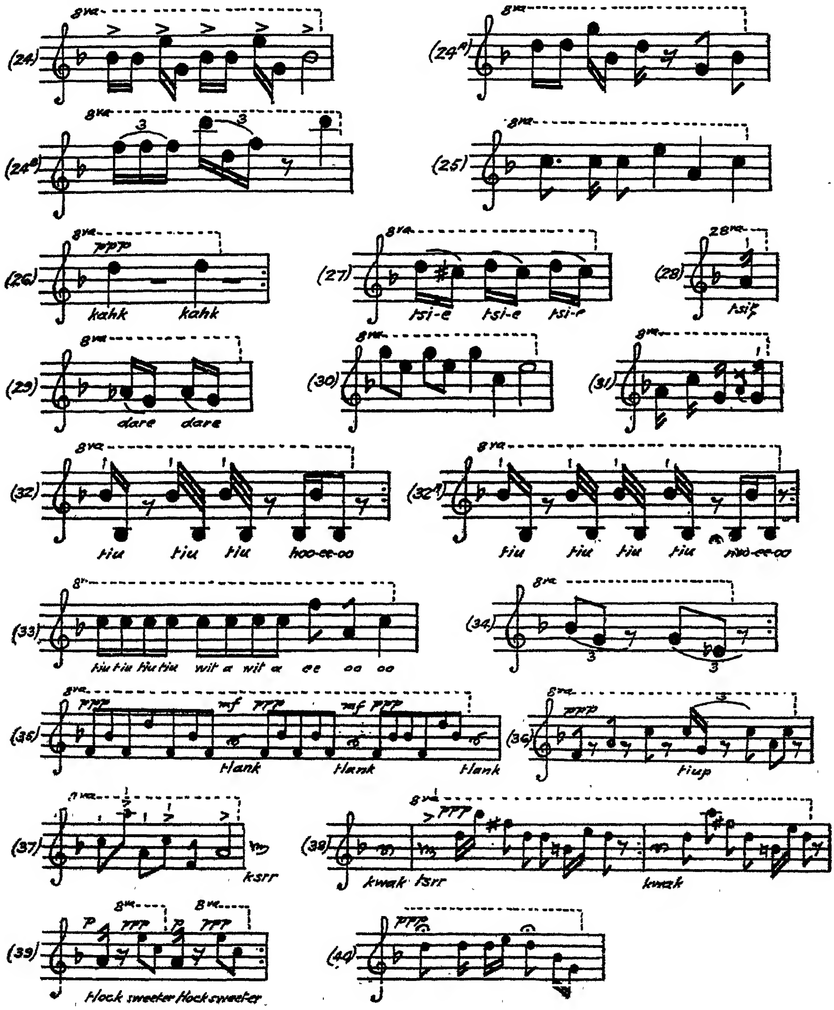
(103)

especially when the high C was taken, yet they were quite musical. On the 16th, in a neighbouring valley, the chorus was carried on mostly in the high-pitched notes, sounding like tiny, light, resonant bells: the highest notes were almost "sweet bells jangled out of tune and harsh," but so softly uttered that, like the unharmonious upper partial tones, they gave character to the chorus rather than discord.

Bell-bird.

On Kapiti the bell-bird, like the tui, was very tame, singing and feeding close at hand. The notes of (24) appeared to be the call-notes. They were the ones most generally heard, and correspond to (1), (2), (7), (8), (10), (13), (14), (17), (17A), (22), and (23). They were very rapidly uttered—eight to ten semiquavers a second. They were clear whistles, excepting the closing note, which was more full and flute-like. This call was varied as in (24A) and (24B). A call somewhat similar, but more flute-like in tone, was (25), taking something over a second. On a day when a strong south-east wind was blowing, a bell-bird, hunting for insects in a ngaio, sang at intervals of two or three seconds a single note on D, (26), almost vocalized *kahk*. It sounded like the beat of a bell blown on the gale from the distant mainland. The slurs of (27) were cried by a bell-bird when swooping after a whitehead. The slur was repeated eight or more times in succession, three or four times a second. The high staccato note (28) was repeated by a young bird, the gape of its beak still white at the base. It was searching, first in a manuka, then in an *Olearia Forsteri*, constantly uttering this single sharp note. Three weeks later the note was F instead of A, and this young bird sat in the top branches of a manuka repeating it incessantly twice a second for minutes at a time. The old birds came one at a time at intervals to feed it. The cry would cease for a couple of seconds whilst the food was given, and then begin

again. An old bird approaching with food cried the notes of (29), repeated six times, about three slurs a second. It was vocalized *dare dare.* Somewhat akin to the call (24) is the phrase (30), sung in about two seconds, the concluding notes being again flute-like. The rapid notes of (31) and (32) are characteristic of the bell-bird: those of (31) are sharp whistles, uttered about ten a second; (32) and the variant (32A) are curious sharp slurs vocalized *tiu*, very quickly uttered, followed by a strange mellow



bell-like triplet vocalized *hoo-ee-oo.* The *tiu* is very commonly used by the bell-bird, but in (33) it is not apparently slurred, the whole phrase being a vocalized whistle, eight or ten semiquavers a second. The phrase (34), taking two seconds, was repeated many times in succession in an obscure ruinous vale, producing a strange, melancholy feeling. Like many bell-bird phrases, this is in perfect time.

The whisper-song of the bell-bird appears to be more definite than that of the tui. I took (35) to be one of the tui's bubbling whisper-songs until I actually saw a bell-bird singing a similar theme. It was sung very softly, with curious interjections separating the phrases, about five quavers a second. Often the *tlank*, or other interjection, only is heard, when it may be known that a whisper-song is in progress, and snatches may be heard on a nearer approach. Similar in character was (37), the phrases being again separated by one of the expletives so liked by the tui. These songs are sung for two or three minutes at a time, are more clear than the tui's, and appear more under the control of the bird. On the theme of (38) was built a long whisper-song, and this song is one of the best examples of art in bird-song that I have heard. It was perfectly regular in time, and each varied phrase was introduced by an expletive. The first part was many times repeated, at times as in the second part, and in several other forms. The notes were mellow, occasionally swelling to a bell sound. At a distance of 20 ft. nothing could be heard but the *kwak*, at regular intervals of about two seconds. When at half that distance the song was barely audible; yet, soft as it was, there was a perceptible swell and dying-away in intensity. The song was sung at dusk, and after continuing for two or three minutes stopped abruptly on my attempting to approach up the slope to hear more clearly. Another bird sat in sight close above me singing the short phrase of (39)—partly a whisper-song, the *tlock* being clear and bell-like. The song (40) suddenly came from close beside me, followed after a moment by the common call.

Kaka.

Noisy as the kaka usually is, the female has a crooning song at breeding-time—a soft, gentle song, quite different from the usual raucous cry. I saw several kaka at Kapiti, but they were quiet: the cry heard was *kree-ah*, as in (1), taking a little over a second, or *kee-aw-w-w-w*, as in (1A), the long *aw* being broken as if by momentary stoppages of the breath. The vocalization was somewhat similar to the cry of the kea, but the sound was fuller and broader. In a secluded valley I saw two kaka sitting on a branch, one a little below the other. The lower bird seemed coaxing the upper with a continual *ke ke ke ke* as in (2), repeated three notes a second, at intervals of two or three seconds, leaning up towards it, shivering its body and spreading it tail at each repetition. This went on for several

minutes, when the upper bird, thitherto quite unconcerned and inattentive, seized the lower by the upper bill, apparently, and shook it. The shaking, however, would appear to be due to the act of regurgitation; the bird was feeding the young one, which waved its wings and sometimes "whined" a little during the shaking. The food was evidently passed into the mouth of the young bird at the end of each quivering. The process was gone through four or five times, the old bird running away each time, or flying to a short distance, and sitting apart for a minute or so. Both birds, when apart, scraped the sides of their beak on the branch, the young one also

opening and shutting its beak and working its throat as if swallowing, but never moving from its place. After a time the old bird flew off, and the young one seemed instinctively to know it was for good, as it shuffled off along the branch and was hidden in the foliage.

PARRAKEET.

The chuckling cry (3), uttered when resting or during flight, was varied as in (6), six to eight semiquavers a second. The *do be quick* of (5), Banks Peninsula, in 1912, was *pretty quick*, on one note, at Kapiti, (7), and on one day the sound was distinctly *pretty dick*, the "*d*" uttered as by one slightly tongue-tied. Buller makes a good deal of a bird, kept on a railway-station, having been *taught* to say "Be quick"; but there is

(6)

(7)

little need for teaching, as this is the vocalization of some of the natural wild notes. None but red-fronted parrakeets were seen, though on one day an exceptionally large bird, bright green from a back view, and seeming nearly as large as a kaka, flew silently from me up a short glade; and as I passed the caretaker's house he remarked that he had seen two exceptionally large parrakeets. These would be the Antipodes Island birds liberated at Kapiti by Dr. Cockayne at the end of 1907, or progeny from them.

WEKA.

In only one pair of wekas could I detect any essential difference between the cry of the male and the female. In this pair the cries were as in (12): the female's was a little higher in pitch, was on one note, and

(12)

sounded shriller. When calling, the male stood erect, with bill and neck stretched upwards, the bill open as the cry pulsed up through the pipe. The deep *mmb* of the male often sounded at the same time as the call.

Art. XXXI.—*Notes on Eels and Eel-weirs* (Tuna *and* Pa-tuna).

By T. W. Downes, Wanganui.

[*Read before the Wanganui Philosophical Society, 17th December, 1917; received by Editors, 31st December, 1917; issued separately, 24th June, 1918.*]

Plates XXIII–XXXIV.

Introduction.

In commenting on the annual report of the Wellington Acclimatization Society the London *Field* says, "Various things in the report make it clear that the big eels for which the country has always been famous continue to trouble the fisheries. The New Zealand eel is a mysterious creature, as to which one would like more information. He reaches an immense weight, and has been credited with being dangerous even to human beings when they are bathing. A monograph of his life-history and habits would be very interesting."

I much regret that I have been unable to find any descriptive matter in connection with our native eels, but in the new edition of Williams's *Maori Dictionary* (1917), under the heading "*Tuna*," the following note is given: "This is the generic name for eel. Nearly a hundred distinctive names are recorded,* many, of course, being synonyms for varieties of the three species observed in New Zealand waters." Five species of fresh-water eels (in addition to the marine conger) are listed by Hutton in his *Index*,† but no varieties are there recorded. Certainly there appear to be a good many.

On the west coast of the North Island, the only district in New Zealand with which I am thoroughly familiar, the eel, or *tuna* as it is called by the Maori, has ever been conspicuous upon the native bill of fare. Indeed, often for months at a time, owing to the fact that they could keep the fish alive, and also as they were able to preserve it by sun-drying, it was their only animal food; consequently a large part of the time of the people was formerly spent in the manufacture of *hinaki* (eel-baskets), *pa-tuna* (eel-weirs), and other implements used in connection with the fishery.

In olden days the *pa-tuna* was an elaborate as well as an exceedingly strong piece of work, often adorned by carvings, and always made to stand years of flood-timber buffeting; occasionally it required repairing, but it was never quite destroyed. To-day on several of the upper Whanganui River rapids there are the remains of old *pa-tuna*, though the huts of the adjoining villages have long since been obliterated by time.

I have heard that the Waikato River, with its tributaries, was the most celebrated in New Zealand for its *pa-tuna* and the quantities of eels found there, right away from the mouth up to the Huka Falls, near Lake Taupo, above which none are found. The Manga-tawhiri, the Maramarua, the

* I am informed by a correspondent that about 110 eel-names are on record, most of which are to be found in the 5th edition of Williams's *Maori Dictionary* (1917).

† F. W. Hutton, *Index Faunae Novae Zealandiae*, London, 1904.

Whanga-marino, the Manga-wara, the Waipa, the Awaroa, the Opuatia, and the two lakes Waikare and Whangape, all in middle Waikato, were famed for their eels. Along all these streams (most of them navigable) the Maoris in former times erected enormous eel-weirs, which have now been destroyed by floods or removed to admit of navigation by launches and barges. On the Maramarua there were most extensive *pa-tuna*, the main posts of which were frequently 2 ft. in diameter, with roughly carved tops. How the old Maoris, without mechanical means of driving, ever got these heavy posts into position is not known, but it must have been a strenuous work. (From notes by Mr. Percy Smith.)

A note from Mr. Best states that he was informed by natives at Huntly, Waikato, that their elders did not construct eel-weirs in the Waikato River, on account of its depth, &c., but set eel-pots in the open river, to which eels were attracted by bait. Weirs of the V form were, however, erected in the numerous tributary streams, more especially those running from the numerous lakes to the river. Eel-pots were also set in the lakes without any form of weir. Eel-weirs are termed *pa rauiri* by Waikato natives, on account of the wattling process by means of which the fences are constructed.

Although the *hinaki*, or eel-pot, is a common object in most Maori villages and in every museum, I do not remember ever having seen it described. Even the late Mr. Hamilton in his fine work on *Maori Art* entirely omitted it. Why this was done I do not know, for a well-made *hinaki* is a beautiful object, fashioned with infinite care and artistic ability, and also made to stand many years of hard use. There are, however, in *Museum Bulletin No. 2* some pictures of *hinaki* of a rather poor class, illustrating an article entitled "Notes on Matters connected with the Sea, &c." In these modern days the *kareao*, or supplejack, and even fine-meshed wire netting, often take the place of the old-time *kiekie* root or *akatea*, but these work-saving substitutes, though perhaps just as effective, are certainly not very artistic.

There is in Hochstetter's *New Zealand* a picture of a *pa-tuna*, but it is a very rough and imaginative affair, and gives but a feeble idea of a weir made for use and wear. Hence I include some photographs which will, I think, illustrate this article better than I can explain by description.

EELS.

The eel enters very largely into Maori mythology,* into which I do not intend to enter, but the earliest reference I have come across regarding *pa-tuna* (eel-weirs) in local history was in Rua-matatoa's time (seventeen generations ago), when a man's leg was carried down the Whanganui River till it was caught in a *pa-tuna* at Hiku-rangi (now Karatia) and afterwards eaten, the result being a civil war.†

In the early volumes of the *Transactions* there will be found some discussion as to whether eels migrate annually to the sea or otherwise, it being pointed out by some writers that they do so, and by others that they are numerous in lagoons that have absolutely no connection with the ocean. It seems, however, to be an accepted theory that eels migrate. According to the natives, and they are keen observers of nature—or, rather, they were—there are many varieties of eels, distinguished by different

* ELSDON BEST, Food Products of Tuhoeland, *Trans. N.Z. Inst.*, vol. 35, pp. 45–111 (see p. 65), 1903.

† See T. W. DOWNES, *Old Whanganui*, p. 51, 1915.

names, but unfortunately, owing to these names varying in different localities, it is impossible to classify them at all thoroughly by Maori nomenclature. One point seems, however, to be established by them to my mind, and that is that some of the species or varieties migrate and others do not.

The eels that travel to the ocean annually are classed under the general name *tuna-heke* (see fig. 1), and the migration itself is known as *whaturoa.* It is for these that the *pa-tuna* are built, and the natives know to within a few days when the eels can be taken. They are never caught with bait,

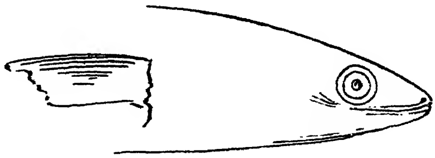


Fig. 1.—Outline of head of *tuna-heke* (*tuna-ngahuru*).

and seldom seen except when they are travelling down the river. The word *heke* implies to migrate or descend. These eels are subdivided into two or three (possibly more) varieties.

The eels that are caught with bait and that remain in one place throughout the year are called *tuna-toke* (see fig. 2)—that is, the eel that takes the worm as bait. This eel also embraces several varieties. It is often taken

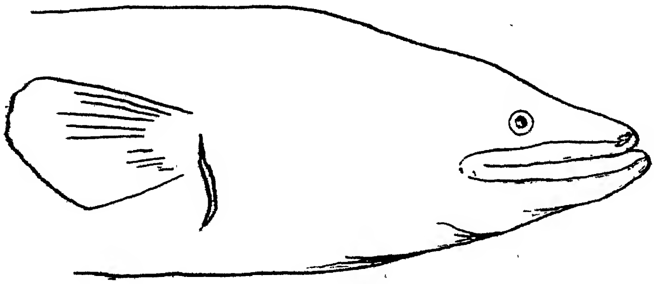


Fig. 2.—Outline of head of *tuna-toke* (*tuna-puharakeke*).

with a baited *hinaki*, but even in streams where it abounds it is an exception to capture one in a *pa-tuna*. Occasionally they are washed down the race, but very seldom. Among over eight hundred *tuna-heke* that I saw taken from the Moumahaki *pa-tuna* last season there was only one *tuna-toke* of the variety called *puharakeke*, although the stream was literally full of them.

It seems to me that this name *tuna-toke* has long been known to the Maori. Upwards of twenty generations ago there lived a certain Whanganui ancestor (so says legend) who adzed out a famous canoe under the water. He used to dive down to his work every day and remain under water till the evening, when the eels, swimming about his legs, gave warning that it was time to cease work. Owing to the exceptional feat performed by this man he was called *Tama-tuna*, otherwise "The son of an eel." This man's eldest daughter was named *Tuna-toke*, and sometimes *Hine-toke*—"Daughter of the worm."

According to local natives, the first of the *tuna-heke* to go down the rivers is *tuna-ngahuru*, an eel with a thick but soft greeny-brown skin seemingly sprinkled with fine gold-dust. A special feature is the large eye, which can be moved independently, with an outer ring of blue, an iris of gold, and a black pupil. The word *ngahuru* sometimes means "ten," sometimes "fruitful" or "abundant," also "harvest-time" and "autumn"; and this name may be given because of the quantities in which this eel is sometimes taken. There is a small *pa-tuna* built in the Moumahaki, about a chain up from where it joins the Waitotara River (see Plate XXIII). This stream is fed by a small lake-system, called Manga-whio, far up the valley, and it is from this source that the eels apparently journey. It was finished on the 1st April of this year (1917), and was just in time to catch the annual *heke*, or migration. About a dozen eels were taken the first night, and this number gradually rose to forty by the 12th, when the first fresh took place. As soon as the water rose about 1 ft. the number immediately increased till it reached over eight hundred for a twenty-four-hours catch. This lasted for only two or three days, when the numbers gradually diminished, and by the 20th the migration of *tuna-ngahuru* was over.

The natives say that it is almost useless to set a *hinaki* on a moonlight night, and also during the daytime; but when the water is at all muddy or discoloured the eels come down in hundreds during the season, day and night alike, except that at night-time they are much more numerous and swim nearer the surface of the water, as proved by the fact that in the daytime the bottom net takes the most fish, and during the night the top one; for whenever the water is deep enough one net is set above another at the mouth of an eel-weir, as will be explained later. When the eels are making this mad dash for the ocean the baskets are examined every hour or so, and, judging by varying success, it seems to me that the migration begins shortly after twilight sets in, is at its height from about 10 p.m. till 2 a.m., and then gradually dwindles down towards dawn as the eels seek hiding-places for another day. With the gathering darkness of the next night they once again take up their swift glide down-stream, and so on till the ocean is reached.

With *tuna-ngahuru* another eel is taken, called *tuna-hau* (Whanganui) or *tuna-hao* (Waitotara), which can easily be distinguished by its silvery belly. Other names for these silver-bellied or allied eels are *puhi* and *pango*. I must confess that I can detect but little difference between the two eels *tuna-ngahuru* and *tuna-hau*. I selected one of each from a large catch on the 12th April: *ngahuru* was very dark-skinned, almost black, and *hau* light-coloured and silvery; yet on the following morning when both were dead they were scarcely distinguishable, both having returned to the colours as first described. The natives are aware of this peculiarity. One person explained it to me by likening *tuna-hau* to a photographic proof that I had given him a few days previous—light and bright at the time, but quite black a few hours afterwards. Both these eels are very difficult to skin; indeed, the skin cannot be removed without tearing away a portion of the flesh, which is somewhat pink.

Another of the *tuna-heke*, or migrating eels, is the *tuna-riri* (Whangaehu) or *tuna-rere* (Whanganui), sometimes called *putaiore*—a blue-black eel with large pectoral fins, rather small mouth and teeth, flat head, tail rather broader than the usual type, and blue eyes resembling those of a sea-fish. The skin is very hard, and absolutely refuses to be removed. This eel is very lively when caught, and is said to be able to jump out of a canoe,

hence its name *riri*—wild, angry. It is esteemed the finest of all the eel family, the flesh somewhat resembling wild pork in flavour. The natives, of course, do not attempt any skinning or cleaning, as doth the uneducated European, but they say that if the fish is dipped in boiling water the slime is at once removed. Those I saw taken at the Kauwae-roa Rapid, Whanganui River, on the 19th April, 1916, were all about the same size, 2 ft. 9 in. long and 8 in. in circumference. I have noticed this peculiarity in connection with other *tuna-heke* that I have seen caught, and it seems to me to be conclusive evidence that only the fully developed (and probably female) eels are seeking a spawning-bed in the ocean; the small and immature fish remain in the fresh water.

Although the *tuna-riri* is usually taken going down the river when the water is discoloured by rain, yet some natives say that occasionally it climbs the rapid, so the *pa-tuna* is constructed to intercept the fish whether it travels up or down. Under ordinary water-level a heavy log, called *huahua*, is placed in the weir, running parallel to the current, and held in position by cross-stakes driven each side of it. This creates a backwater running up the swiftest rapid, and as the eel swims up this channel he takes advantage of the assistance so given to climb the rapid. As soon as he reaches the top he follows round a smoothly dressed post placed right at the head of the weir, leading to the inside, and he is immediately caught by the strong current and thrown back into the net leading to the *hinaki*, or eel-pot, at the foot of the weir. Patonga, my Waitotara informant, stated that *tuna-riri* will not preserve by sun-drying, as does the ordinary *tuna-toke*, but this is questioned by the Whanganui people. The catch lasts only two or three days, and while it is being dealt with the eels are transferred to large baskets, called *puwai* and *puhara*, made for this purpose, and also spare *hinaki*, and then put back into the water to be sorted out at a more convenient time. When all available baskets are full the surplus fish are put into holes, called *parua*, dug in the clay, and covered with fern, where they will keep alive for a day or two.

The favourite way of cooking the smaller eels is to grill them. They are taken out of the baskets and killed by a cut behind the head which severs the bone. Without further treatment they are strung close together by a thin stick being passed through the heads, and then placed on a grid over a fire of embers—usually, in these degenerate days, on some fencing-wire or wire netting. This method of cooking is called *rara*, and the eels so treated are certainly very good if one could only get over the idea of grilled entrails and slime (*paratea*). As a matter of fact, the entrails of all the *tuna-heke* variety are very small, most of the inside of the fish being filled with what appears to be fat or undeveloped roe. This part to the Maori mind and taste constitutes a special delicacy.

Those I have examined have shown no traces of food, consequently I am inclined to think that these eels, like the salmon, travel on empty stomachs.

Other eels caught in the *pa-tuna* are *tuna-paranui*, a black eel; *ruahine*, very large but short (one of this variety weighing 38 lb. was caught last year on the upper Whanganui); *arawaru*, not so thick but longer than *ruahine*; *mona-nui*, a small variety; *tuna-keke*, somewhat larger; *tuna-kuia*, the largest of all, and filled with roe, or probably fat, only seen and caught for two or three days each year. Of the above the only eel that I have had an opportunity of seeing was *ruahine*. On the 2nd May, 1917, the large eels commenced to go down the Moumahaki, and fourteen of these immense fish were taken on that date. The smallest probably weighed

12 lb., and the largest was, according to native measurement, 6 ft. 1 in. in length and 20 in. in circumference. I went down to the Ngutu-wera settlement immediately I heard of the capture, but found the large eel had been taken to Waitotara. It was found dead in the *poha* (leading-net), where it had been jammed by sticks and debris. The rest of the catch was emptied out for my inspection, but as far as I could judge by match-light, although they were called *ruahine*, they were very similar to *tuna-ngahuru* except in the matter of size.

Although the natives here affirm that *tuna-ngahuru* and *tuna-riri* are different varieties, I am not at all sure that this is so. I have seen both eels, but not in the same year, and, as far as I remember, they showed the differences as described; but different localities and conditions may have caused the slight variation that is to be found. However, to the natives they go under different names, and they readily detect the difference.

According to Te Whatahoro, a well-informed native of the East Coast tribes who has contributed largely to our store of Maori information through the Polynesian Society, the names of the *tuna-heke* and the order in which they go down the East Coast rivers are as follows:—

"The first and smallest to be taken on the East Coast *pa-tuna* is *tutuna*, called *tuna-riki* by the Waikato people. It goes down the rivers during November, December, January, and February. It is the smallest of all the eels.

"The next is *tuna-hau*, also a small eel, about 18 in. long and 1 in. through. It is dark-skinned, with a fine head and large eye. It is of exceptionally fine flavour, and is usually cooked by the *rara* method. It is one of the best varieties to dry, and will keep in good condition all the year. It is prepared for this process of preserving by the finger being inserted down the throat and the entrails dragged out through the mouth, great care being taken not to injure the skin, as that would allow the flies to enter. Soaking brings the fish back to the standard of fresh fish. This eel is considered and reserved as a special food for chiefs and visitors.

"Next comes the *mata-moe* (sleeping-eye), about 2 ft. 6 in. long and the thickness of one's wrist. It is taken from sandy or stony rivers, and is very fat and good. It occasionally takes bait (*mounu*), but is one of the fine-head and migrating varieties. There is a sort of film over the eyes of this eel, giving it a blind appearance; hence its name. It is taken from November to May, but is not common.

"Next comes *tuna-reko*. This eel has a silver belly and is of a light-grey colour. It also is somewhat scarce, and goes down during February and March.

"After *tuna-reko* comes *kokopu-tuna* and *ruahine*, which go down together. They are both large (about 5 ft. long), but *ruahine* has a fine head and is soft and fat, while *kokopu-tuna* is coarse and has a head resembling the bull-dog type of the *tuna-toke* varieties. It has to be handled carefully, as it will endeavour to bite, and when it does so the episode will long be remembered. I once saw an old man named Horomona who had been bitten on the shoulder as a child, when bathing in the Parapara-kino River, South Island, by this eel. It must have been an ugly flesh-wound, for even in old age there was a long deep scar. I disbelieved the story at the time, but have since then heard of others who could speak from experience in regard to an eel-bite. I myself was bitten as a youth when trying to extract the hook by which a large eel had been caught, but it was, I think, *tuna-puharakeke* that got hold of me on that occasion.

"*Kokopu-tuna* is not really a *tuna-heke*, for it is seldom taken in the *hinaki*. It is usually speared lying in shelter of *raupo* (bulrush) or rubbish. *Ruahine* goes down between the months of February and June.

"The *kopakopako* is a swamp-eel about 2 ft. 6 in. long and 2 in. in diameter, having spiny fins and being very bony right from the back of the neck to the tail. It is very poor food, and is dried and stored only in case of famine.

"Another eel, called *tuwerewere*, has similar spines, and is also very poor food. It is the last of the eels to go down-stream."

Two other eels mentioned but not described by Te Whatahoro were *hau-mate* (small) and *karaerae* (about 24 in.).

As before mentioned, none of the *tuna-heke* take bait, such as worms, *weka* (wood-hen), &c., the natives affirming that they live on water and foam (*kohuka*). The great *heke*, or migration, seems to take place during March, April, and May, but the natives have no record of the large eels returning. The young fry go up the rivers in the spring in countless numbers. I have taken them in a whitebait-net in October, but am told by the natives that they continue travelling up-stream till well on into the summer.

Of the *tuna-toke*, or "worm-eating" varieties, often called *tarehe*, usually taken with a *hinaki* baited with native worms, pigeon, or wood-hen, the principal eel caught is called *tuna-pa* in the Whanganui district. It is said to be the favourite variety of *tuna-toke*, and is always roasted by the *rara* method, being considered a delicacy when so treated. The baskets are placed in a favourite locality in the late afternoon and raised the following morning. Often the *hinaki* contains 1 cwt. or even more for one setting. The most I ever saw taken with baited *hinaki* was at Kaiwhaiki, Whanganui River, in 1907, when something over 3 cwt. was netted from two large *hinaki* in a single night.

Tuna-iakaaka is another eel taken with *tuna-pa*. It is of a light-green colour. It is considered inferior to *tuna-pa*, and requires a considerable amount of boiling. It is never grilled.

Tuna-puharakeke, the large yellowish-brown-skinned eel with which most of us are more or less familiar, is also taken in the *hinaki*, but usually by the bob (*tari*) made of the large native worm strung on dressed flax (*muka*). At a small creek called Manga-weka that runs into the Moumahaki near Ngutu-wera I have seen the Waitotara natives drive this eel to a narrow part of the creek where a trap had been prepared. When an eel is disturbed it seems to invariably travel down-stream. The natives therefore go into the water and make all the commotion they can, working downstream, while one man stands with a deep basket, called *rehereh*e, at the narrowest part and lifts the eels as they enter, one or two at a time, and quickly transfers them to a sack. While I was watching the fishing at this stream about a quarter of a potato-sack of large eels was taken in two hours by three men. When fishing for this eel with a hook the natives use lamprey (*piharau*) as bait if at all procurable, as the *puharakeke* is very greedy for this food and will take it when it refuses everything else.

Tuna-puharakeke has a large head, small eyes with a black pupil, ring of bright gold, and an outside ring of dull gold. The lower jaw protrudes somewhat, giving the bull-dog appearance, and the teeth are sharp and set very thickly, running back like a wedge on the roof of the mouth. The under part of the head is whitish. This eel often grows to an immense size. Some years ago I saw two extremely large ones taken out of a *hinaki* near Upoko-ngaro. Their weights were respectively 46 lb. and 32 lb.

The natives were very much excited when they were caught. The large eels of this variety are usually dried for winter use, although they can be caught throughout the year. In sun-drying, the heads are taken off; they are skinned and split open, the bone being taken out, and they are then dried for several days on stages, when they will keep for several months. This eel is usually boiled or steamed with potatoes in an *umu*, or steam-oven.

Another yellowish eel is *tuna-kaingara*, which is said to be poor and lean. It has a large head, is readily caught with the bob, and does not go to the sea with the April floods.

In the upper reaches of the Whanganui River there is a tributary known as the Ohura, which, owing to its situation and formation, is a most suitable place to capture the young eel-fry as they go up-stream. This little eel, varying in size from 2 in. to 6 in. in length, is called *tuna-riki*, and the Maori up till a generation ago used to journey down from Taumarunui and up from Pipiriki to procure this delicacy. The fishing commenced in the early summer, long after the *tuna-heke* migration was over, and lasted for two and sometimes three months. The manner of taking *tuna-riki* was as follows: At the mouth of the Ohura there is a small waterfall, 4 ft. or 5 ft. high, at the foot of which is a very deep pool. The little fish congregate here in countless numbers, probably waiting for a flood to enable them to mount the obstacle and continue their course up-stream. Loose bundles or balls were made by the native women, who rolled fern, rushes, and *manuka* together until the mass reached about the size of a football. These were then tied up with flax to hold them in shape, and let down into the hole at the foot of the fall overnight, being held to the shore by flax lines. It is said that these little fish are very curious and attracted by anything new, and so crawl into the balls in great numbers. I have an idea that they may be attracted by the fern-pollen, but I may be wrong in this. These bundles are called *koere*, and the Maoris say that two small balls are much more attractive to the fish than one large one. When the *koere* are lifted in the morning they are shaken over a kit, and the eels drop out. Captain Mair* has a note on this little eel, in which he says that between 2 cwt. and 3 cwt. were taken in a single night by hanging funnel-shaped bags on the Ohura Falls, up which these little eels were making their way in thousands. I have not seen the natives fishing in the manner described by Mair, but saw upwards of half a sack taken by the *koere* method about twenty years ago.

At the Waitangi Falls, Bay of Islands, which are some 20 ft. in height, composed of basaltic rock, the water falling vertically into a deep pool subject to tidal flow, Mr. Percy Smith informed me that he had seen thousands of young eels, from 2 in. to 6 in. long, wriggling up the rough rocky surface, where a thin film of water descended. The Maoris came to the falls in their canoes and scraped the young eels into baskets for food.†

There is an eel well known by repute to all the river natives of this district. It is called *tuna-tuhoro*, and is described as a black eel about 3 ft. long, with a very large head and small tail. Now and again it is hooked, and occasionally it is found in the *hinaki* with other eels. It is a fish of ill omen. When the natives were building a *pa-tuna* on the Au-tapu Rapid, Whanganui River, four years ago, and had ten timbers driven into

* Notes on Fishes in Wanganui River, *Trans. N.Z. Inst.*, vol. 12, p. 316, 1880.

† Sir Ray Lankester notes, in *From an Easy Chair*, that in England young eels are sometimes seen "wriggling in numbers up the face of a damp rock or wall ten or fifteen feet high."

the stony bed, they saw a *tuhoro* swim past. They immediately gave up their work and started again on Te Aute-mutu Rapid, lower down the river. All the natives dread catching this fish, for should a Maori be sick or any near relative be ill at the time when a *tuna-tuhoro* is caught death always follows. There is no alternative: the patient simply must die. Of course, this eel is never eaten. The effect is quite bad enough if it is simply seen or caught. It seems to be scarce, for Patonga, the old Waitotara native from whom I obtained most of these notes, had never seen one, though, of course, he knew of their dread power. I have been more fortunate. During the summer of 1916 a fisherman dragging a net in the lower Whanganui meshed a small one, about 18 in. in length. The natives who were assisting immediately raised such a commotion that the man took notice of it, and eventually brought it to the Whanganui Museum. I was secretary of that institution at the time, but had not thought of writing on eels, so took but little notice of it. It was, however, without slime, and seemed capable of inflating the throat, thus causing the head to appear larger than its natural size. This specimen was placed in spirits, so that it can be examined if thought a new variety. It is said that it is a very fast swimmer.

Mr. Percy Smith tells me that this eel is known to the Kaipara natives as *tuoro*, and that it is looked upon in that place as being somewhat mythical and harmful to man. It is said to be found in the lakes on the North Head, and was described by the natives as being very large, almost as big as a man's body, with a great lump on its tail. It was supposed to come ashore and chase men, who could only escape by passing over ground where the fern had been burnt. So much for Maori beliefs!

I was in the Upper Ohura district a short time ago, and when there heard some bushmen speaking of an eel with hair or bristles on its back that is to be found in some of the creeks near the Ohura Township. I was unable to see any natives at that time, but shortly afterwards met an old Maori at Taumarunui who recognized my description as *tuna-piki*, or the feathered *tuna*. Further, as I had heard that Mr. W. K. Williams, of Ohura, had seen the eel, I wrote to him and obtained the following reply:—

"Some years ago, when passing a Maori *pa*, I saw quite a number of eels hung on poles in front of a Maori *whare*, and upon examination I noticed these eels had a sort of bristle upon their backs, starting about 4 in. behind the ears and terminating at the tail. Their ears were about ¾ in. long, shaped exactly like a pig's. The ears were slightly forward and up, and gave the eel a most peculiar appearance. The eels varied in size from 18 in. up to 5 ft. Their colour was dark—almost black—at fin, along back, and getting a little lighter towards the belly. The belly was of a cream or pale yellow. . . . I understand they are caught with both *hinaki* and line at the headwaters of the Ohura, in a stream called Waikaka. The Maoris stated they were plentiful."

The mud eel is called by the Maoris *tuna-kohau*, and the salt-water or conger eel *tuna-koiero*, *koiro*, and *ngoiro*.

In some districts an eel called *kaueri* (?) is largely taken by spearing, but the Whanganui River does not lend itself to this mode of fishing. I remember as a boy seeing native women spearing in the Turakina River, and I also remember finding a bundle of spears in a hollow cabbage-tree near a large swamp at Turanga-waikanae, below the Bulls racecourse, some forty years ago. The spears were made of several hardwood points lashed to a handle, and were called *matarau*. Although this mode of taking fish has fallen into disuse in the Whanganui lagoons, I am told it is still common

in the Manga-whero. The usual procedure was to probe among the water-weeds and roots along the banks of a creek, lake, or swamp, and when an eel was struck this was easily ascertained by the vibrating feel. The hand and arm were next put down in the water, so that the eel was held to the prongs while it was being lifted.

About the year 1880, when visiting the Kai-kokopu Lake, a large lagoon in the Lower Rangitikei district reserved to the natives for eel-fishing, I saw some natives of the Ngati-Apa Tribe empty some small eels from a *hinaki* into a fire they lit at the edge of the lake, from which the scorched fish were allowed to crawl back into the water. On inquiring the reason I was told it was an old custom, called *tunutunu-ki-te-ahi* (roasting at the fire), and was supposed to make the eels that escaped large and fat.

In many low swampy districts near the sea there are extensive sand-flats, and it was formerly a common practice for the natives to make a cut or drain from the lagoons or swamps near by to well out on the sand-flats. After heavy rain causing the swamp waters to rise a few inches the eels endeavoured to get out along the cuts, and were soon left struggling on the sand. I have seen upwards of 1 cwt. of fish so gathered (one New Year's Day) on the large sand-flat north of the Rangitikei River mouth. In the Whanganui deed of purchase similar eel-cuts from the Kaitoke, Wiritoa, and other local lakes are mentioned as native reserves.

Yet another method is occasionally adopted in taking the *tuna*, and was practised on the Okorewa, down which tons of eels annually migrate from the Wairarapa Lake. If a man has no *hinaki*, or if the *pa-tuna* are constructed too close for him to get another in, a shallow drain is dug from the river across the sand, terminating in a large hole. He watches the eels swim past till he considers he has enough in the hole, blocking with a stick any that seek to return. Then the drain, and later the hole, is filled with sand, quickly smothering the imprisoned fish. Such a place is called *awa-one-huna*.

The following is a list of the west-coast (North Island) eels given by an old bedridden Waitotara man named Patonga:—

Tuna-pa.
Tuna-riri (sometimes called *tuna-putaiore*).
Tuna-taiaka. Described as an eel with a fine head and hard skin, that will not boil tender.

Tuna-kaingara.	*Tuna-tangaroa.*
Tuna-ngahuru.	*Tuna-tuhoro.*
Tuna-hau.	*Tuna-puharakeke.*
Tuna-opuha.	*Tuna-kaueri.*
Tuna-ruahine.	*Tuna-arawaru.*
Tuna-kopure.	*Tuna-riki.*
Tuna-paranui.	*Tuna-monanui,*
Tuna-keke.	*Tuna-kuia.*
Tuna-kohau.	*Tuna-iakaaka.*

As a rule, the prefixed generic term *tuna* is not employed. In regard to the *opuha* and *iakaaka* it is possible that a missing *h* should be inserted.

The following are the names of eels as supplied to Mr. Percy Smith by Aporo te Kumeroa, the late well-known chief of Wairarapa, and are all said to be found in the Wairarapa Lake or the rivers flowing into it:—

Matamoe (also called *hikumutu*).
Hao (also called *puhi*). This eel has blue eyes, and is the best eating of all.

Riko. The largest of all. Te Kumeroa said he had seen them 6 ft. long.

Kokopu-tuna. Very large. There are two kinds: *paratawai*, a short one, and *putake-harakeke*, reddish in colour.

Haumate. Like the *hao*, but with short ears.

Karaerae.

Kopakopako. Silver-eel. The Ngai-Tahu people call this *pakeha*, a name they used long before the advent of the Europeans.

Tarehe (called also *tirehe* and *mairehe*). A silver-eel; is short, and not the best eating.

Kongehe. Can be caught with the hand. Soft and flaccid.

Tatarakau. Same thickness head to tail; black like *riko*.

Piharau.

The lamprey (*piharau*) is about 18 in. or 20 in. long, with a cartilaginous skeleton. It is considered a great delicacy by the Maori, but is difficult to preserve, as it cannot be dried or smoked. My informant stated that the longest time it can be kept fresh is four days. It is therefore put into holding-baskets (*korotete*) (see Plate XXVIII, fig. 3) and kept alive for months. Other natives say that the *piharau* can be preserved by drying, but the method is somewhat different to that employed for eels, as they are partly sun-dried and then finished by a slow fire. It goes up the rivers in considerable numbers during May, June, July, and sometimes August, and returns to the sea in October and November, when the skin is very soft. It is taken in the *hinaki* during flood-time only, at a weir built from the shore at right angles into the river. This is called *utu*, and is exceptionally strong. The *piharau* is taken as it goes up the river, climbing close to the shore to avoid the current. Although it is seldom seen swimming up-stream (I have only seen one, although often motor-launching on the upper river), yet great numbers are sometimes taken. On the 2nd May, 1917, 1,434 were lifted from the *hinaki* at Kai-manuka, Waitotara River; and in the Waitara, for a single night's netting during a fresh in June, three sacks were filled—probably between two and three thousand.

In some districts another method (called *whakarau*) of catching *piharau* was adopted, but has now fallen into disuse. A large thick mat was manufactured of bracken laced together with flax. This was about 4 ft. wide, and was pegged down in the river right up to the shore with parallel rows of pegs. This was laid down in a sheltered spot with either a natural or artificial breakwater, and the *piharau* would shelter and hide in the provided cover. Two men would walk out into the river and roll the mat up, working towards the shore, and, of course, taking the fish with them. It is said that many were taken in this manner; but nowadays, I am told, a sheep-skin is used (I do not quite understand how) instead of the bracken mat, and is almost as effective, and has the merit of being simpler.

The Taranaki natives say that in former times they used a certain sand (brought from Hawaiki!), which was placed in a little stone cup called *punga-tai*, and, having had charms said over it, this cup was deposited in the river near the *pa* and attracted the *piharau* to it. *Tau mahi, a te Maori!*

Other Fish taken in Eel-weirs.

The small fish taken in the *pa-tuna* at the same time and mixed with the eels are *kokopara* and *pangohengohe*, probably the mountain-trout; *toitoi*, a

small blue fish rather full of bones; *inanga*, a fish about 5 in. long, almost transparent, with white belly; *atutahi*, a larger variety, or probably a larger fish of the same family; *papanoko* (sometimes *papanuku*) and *panokonoko*, varieties of *kokopu; titihimi*, the smelt (sometimes *ngaure* when young and *takeke* when large); *mawhitiwhiti*, the shrimp; and *upokororo*, sometimes the grayling and sometimes the name given to a small fish about 6 in. in length that is taken only during flood-time. The latter has red fins, and is said to be rather delicate in flavour. All these fish are boiled whole, and, in eating, the flesh is drawn off the bone by a sucking action of the mouth, the head and bone being thrown behind over the shoulder. The water in which they are boiled is used as soup.

It is said that the *kokopu* and other small fish are not as plentiful as formerly, the introduced trout being responsible for the decrease. About the year 1880 my father was engaged in a survey near Parikino, Whanganui River, employing natives as linesmen, who one Sunday brought a full sack of these little mixed fish to the camp. It was only one of three that had been taken that day on the Parikino Rapid.

In Best's paper already referred to there will be found a great deal of information dealing with these "small fry"; also in *Illustrations for White's Ancient History of the Maori* there are a few plates illustrating various ways of catching and preserving *inanga*, *piharau*, and *tuna*, but the methods as pictured are not practised in this district, so will not be touched upon in this paper.

In Mr. Cowan's *Story of Kimble Bent* mention is made of the Taranaki natives catching *piharau* by torch-light; but this method also is unknown here now.

EEL-WEIRS.

Eel-weirs were in many cases assigned proper names in former times, as also were sea-fishing grounds and rocks.

The *pa-tuna*, or eel-weir, is of two or three types, one for small streams and others for rivers. I will endeavour to describe those I am familiar with.

The Pa-tuna *for a Small Stream.*

The timber used in its construction is *kopuka* (white *manuka*), if procurable; otherwise the ordinary *manuka* is used. It is carried as near the site as possible, together with the rest of the required material, and then each stake is carefully prepared by two men for driving, one holding and turning, the other sharpening and trimming off the head so as to prevent splitting in driving. The stakes are given a long tapering point, and as soon as they are prepared they are carried to the canoes. In one I saw built at Moumahaki a full day was spent by a company of eight men in trimming these stakes, together with the horizontal logs, which are of *totara*, and are carefully stripped of sap and have heads formed at the heavy end of the timbers, which are placed down-stream. The lashings are all of split supplejack (*kareao*), and each stick is securely tied by crossing and recrossing the vine in the form of the letter X. Driving the prepared stakes and lashing on the horizontal timbers took the company another ten hours.

The Moumahaki Stream is between 30 ft. and 40 ft. wide at the chosen site, a spot where the banks rise sheer out of the water, and the most confined spot to be found. Fences are built out from both banks at opposite points, running down-stream and gradually converging to a point. These fences are about 30 ft. long, and they close to within 18 in. or so of each

other and then return at a sharp angle to the bank. The fences are constructed of rows of stakes placed within 1 in. or 2 in. of each other, which are held firmly in position by horizontal beams lashed on. (See fig. 3.)

While this work was progressing other natives were employed cutting and sorting out *manuka* brush and bracken. The latter is carefully tied into small bundles about 2 in. in diameter, and lashed to the stakes under the water, stems up-stream. Other stakes are driven in to assist in holding the bundles, which are forced down until they form a solid mass through which even the water can scarcely find a passage. About 1 ft. above the ordinary water-level *manuka* brush takes the place of the bracken, as it is stronger and, being on top, can be more easily repaired than the bracken, though the latter lasts much better than the *manuka* in the water. This *manuka* brush is also closely wattled together and carried right to the top of the stakes. The whole fence is then securely lashed from the heavy horizontal timber (which in this small type of *pa-tuna* is on top) to the shore by heavy cross-beams, especially strong sticks being carried from the angle of the *pa-tuna* down-stream to the shore. Two heavy posts are next driven in about 1 ft. down-stream from the mouth of the weir, one opposite each angle, to which they are securely braced, and they are also braced to each other.

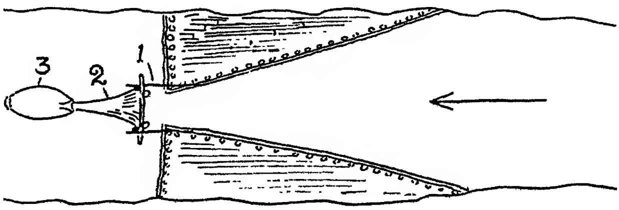


FIG. 3.—V-shaped weir. The arrow shows the direction of the current. 1, braces; 2, *poha*; 3, *hinaki*.

These carry the *poha*, or leading-net, which is shaped something like a huge phonograph-trumpet, with diamond-shaped meshes, which appear to the uninitiated to be too large; but apparently the eels, in the full force of the strong current, which converging to such a narrow point is exceedingly swift—indeed, it is quite a miniature waterfall—are unable to detect this way of escape. The small end of this net is securely sewn to the mouth of the *hinaki* with green flax (*harakeke*), and four cross-pieces of *manuka* about 5 ft. long, notched where they intersect, are then fastened to the large end of the leading-net, which is held open by a large hoop made of *akatea* vine, and this is slipped behind the two posts at the mouth of the weir and held in position by them, and all is ready. (See fig. 3.)

The post inserted away from the end of the fence in order to hold the *poha* in many cases had its upper part carved into the form of a human head. The last such seen in this district was in a weir on the Matahiwi Rapid of the Whanganui River in 1878.

Quantities of *manuka* branches are pegged down between the fences and the shore until the whole creek is forced into the newly made channel. The first night the *hinaki* were set after the completion of the Moumahaki *pa-tuna* twelve eels were taken; a few nights later forty was about the average, except when the moon was bright (the eels apparently do not travel on a moonlight night), until the first fresh took place, when the numbers

immediately increased to hundreds. When the fish are going down-river freely the *hinaki* is visited and changed every two hours. The *poha* and *hinaki* attached are lifted into a canoe, and the eels transferred to a *puwai* (holding-basket) or another *hinaki*, and while this is being done other men drop a new leading-net and *hinaki* behind the posts, working from the *pa-tuna* itself, and pushing them to the bottom with the feet.

The men are quite naked, and it seems to me to be cold and somewhat dangerous work. When a fresh is in evidence the men are often immersed nearly up to their necks when pushing the under-net into position, and it takes all the power of two strong men to hold the operator from being swept away by the fierce current; add to this the darkness, and I am convinced that few Europeans would care to take up the work. The nets are lifted by means of a supplejack rope, which is attached to both leading-net and *pa-tuna*. The *hinaki* is allowed to swing with the current. Occasionally it breaks away, usually during a flood, when driftwood cuts the *poha* net to pieces. I myself have at various times found three, two containing eels and one lampreys, that had so broken away. In flood-time, when the water is deep enough, two *hinaki* and *poha* are set, one above the other. In a high flood the *pa-tuna* cannot be operated upon, and in this way the natives often miss the season's catch.

By the arrangement of this type of *pa-tuna* eels are taken going down-stream and lampreys going up. The eels are carried down-stream by the full force of the current, without chance of escape, and the lampreys going up-stream attempt to enter the current between the posts that hold the leading-net and the angle of the *pa-tuna*, the only possible way, and are immediately swept back into the *poha* net by the force of water.

The first night the *hinaki* were placed at the Moumahaki *pa-tuna* twelve eels were taken, as before stated. The following morning a *tohunga* (priestly adept) very carefully opened the basket just a little, and the first eel that crawled through into the canoe was killed and taken away by him to a secret place unknown to the rest of the Nga-Rauru people. Thereafter the rest of the eels were *noa*—that is, suitable for common food.

Formerly the first catch from a new *pa-tuna* was divided into three parts; in the case of a large weir which accommodated several baskets the outside basket—that is, the side away from which the fishers resided—was taken and so divided. The first division or third was for the gods only, and was cooked in a separate *umu* (oven), placed in flax baskets called *kono*, into which the eels were coiled without breaking, and deposited in some sacred place. The second division was for the women, and was eaten by them while the last division was being prepared. The food-baskets in which it was placed were called *tapura* or *tapora*; those for the last third, for the men, being designated *rourou*.

The names of the various parts of this *pa-tuna* are as follows: The upright stakes are called *matia*, but usually *pou*; the heavy horizontal beam, *huahua*; the braces, *tapapa*; the two strong posts to hold *poha*, *pou-rerenga*; the water-race, *ia*; the bundles of fern matted into walls, *pakipaki*; the *manuka* bundles pegged down, *tapapa*; the mouth of the *pa-tuna*, *ngutu*; the fern-matted fences, *karapi*; the maul for driving stakes, *ta*.

In rivers of some width this V-shaped weir may be repeated two or three times, as VVV, thus providing two or more outlets, or *waka*, at each of which a head-net and eel-pot would be placed. Such a weir was seen in the Waikare-taheke River about twenty years ago.

The Poha (*Waitotara*) *or* Powha (*Whanganui*).—The *poha*, or guiding-net, is constructed of green flax split into about $\frac{3}{8}$ in. strips and woven into about a 2 in. mesh. The knot is the same as that used in the construction of ordinary fishing-nets. The *poha* is always made by men, the women being engaged in making baskets for holding *inanga* and *kokopu*. The mesh is regulated by the first two fingers of the left hand. The net is commenced at the small end, and as soon as possible it is suspended and worked downward (Plate XXIV), gradually being enlarged to 4 ft. 6 in. or 5 ft. by adding meshes (see fig. 4). The small end is about 9 in. or 10 in. in diameter, according to the size of the *hinaki* for which it is being made, and the length 6 ft. or more. The *poha*, when finished, is fastened to a hoop made of a strong *akatea* vine (in modern days more often to a few strands of fencing-wire), which is in turn fastened to a square of *manuka* poles lashed together, with projecting ends to catch behind the two posts in front of the *pa-tuna* (see fig. 5). When a fresh is in evidence the *poha* lasts only about two nights, as it is quickly torn to pieces by the strong current and odds and ends of timber forced against it. The small end is securely sewn to the *hinaki* with green flax.

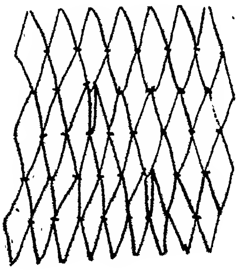


Fig. 4.

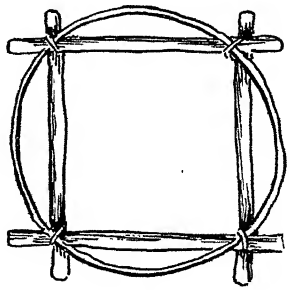


Fig. 5.

Fig. 4.—Method of enlarging *poha* (*whakatepa*).
Fig. 5.—*Poha* hoop (*kaututu*) attached to frame (*tekateka*) for holding in *pa-tuna*.

The names of the *poha* parts are as follows: The vine hoop, *kotuku* (Waitotara), *kaututu* (Whanganui); the *manuka* square to which the above is lashed, *tekateka;* the mesh, *mata;* adding extra mesh, *whakatepa;* the small end, *pihanga;* the large end, *waharau;* the complete net before hoop is put on, *purangi.*

The Pa-tuna *for a Large River.*

This *pa-tuna* is always built with the top end on the crest of a swift rapid, and consists of two parallel fences with cross-returns of a single post facing each other at the foot to hold the *hinaki*. They are exceedingly well built, and very strong considering they are erected in the middle of swift waters from canoes that have to be held in position by poles, and also where the river-bed is composed of boulders and large stones. I am informed by the natives that the fence on the western side is always the shorter, but no reason is obtainable why this is so. Reference to the illustrations will enable the reader to see that this form of weir, composed of two straightened parallel fences, differs widely from the V-shaped weir employed in many rivers, and also from the lamprey-weir, which extends from the river-bank outwards at a right angle to the current. (See Plate XXV, figs. 1 and 2.)

Small *pa-tuna* of the V-type at Ngutuwera, Moumahaki River

Making a *poha*, Waitotara.

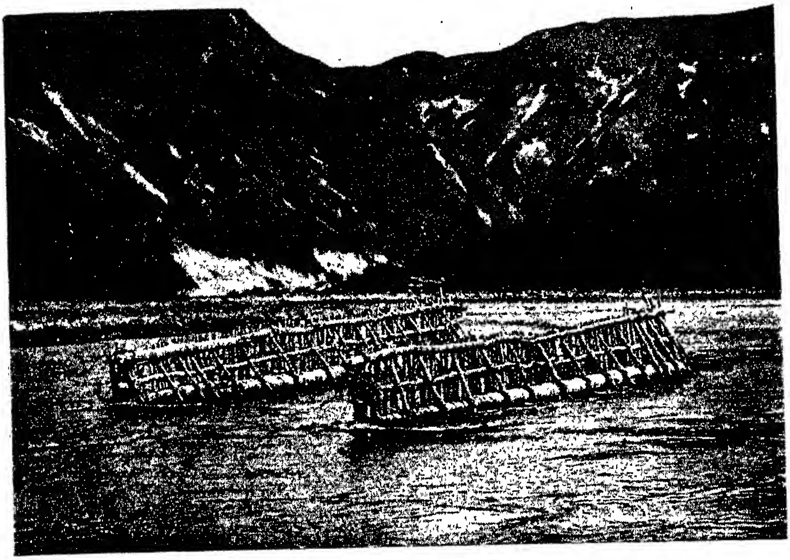


Fig. 1.—*Pa-tuna*, or eel-weir, at Kauwae-roa, Whanganui River, looking down-stream.

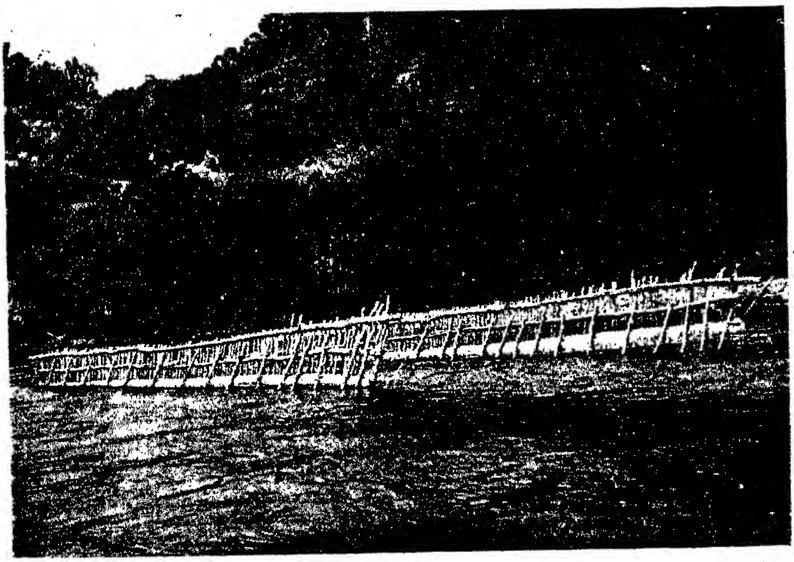
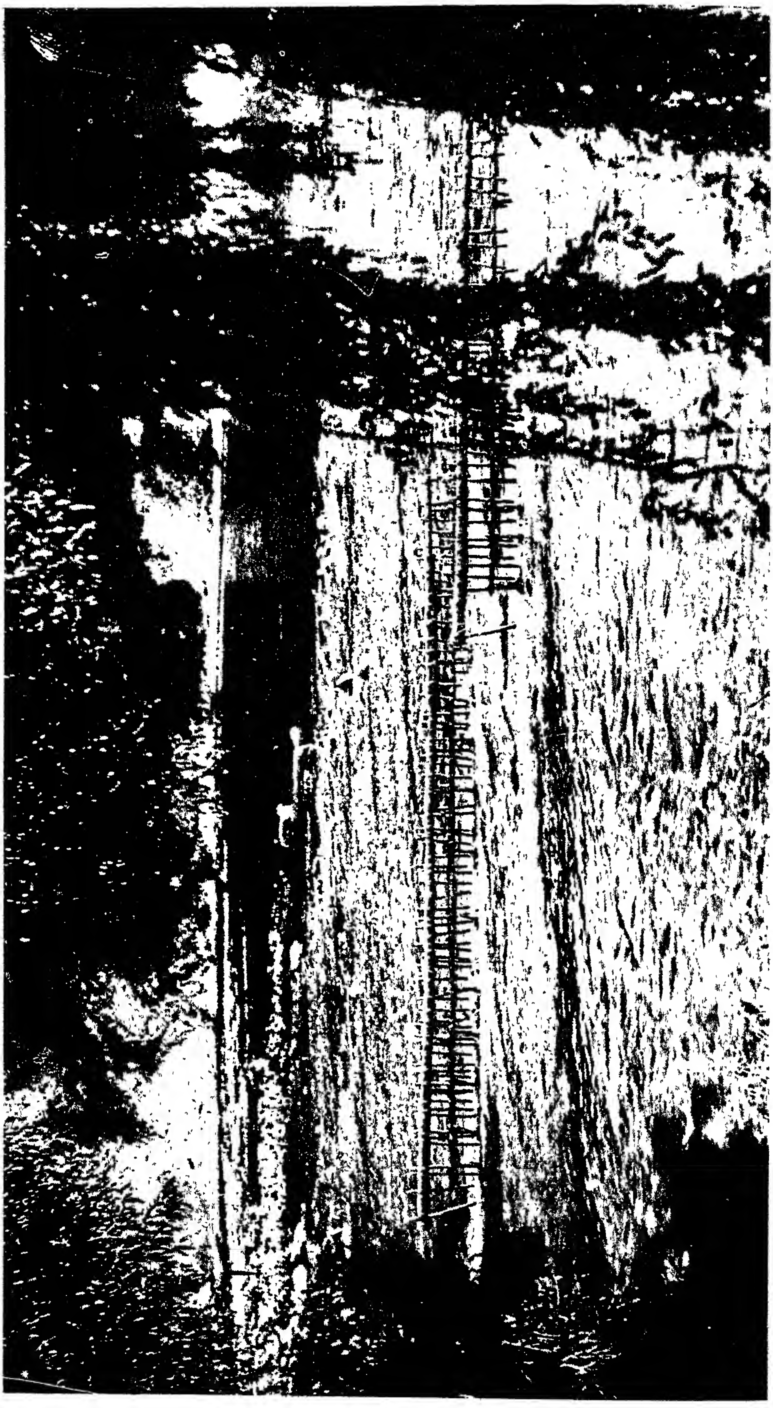


Fig. 2.—*Pa-tuna* at Kauwae-roa, Whanganui River, looking up-stream. The right-angle return posts, or wings, have been carried away.



Pa-tuna on Te Aute-mutu Rapid, Whanganui River (damaged).

After getting all the poles, timbers, and lashings together, it takes from four to six men at least seven days' hard work to construct the simplest form of this *pa-tuna*. The hardwood stakes of *kopuka** are, as a rule, about 4 in. in diameter, and they are driven into the heavy shingle from 2 ft. to 2 ft. 6 in. with a sort of wooden maul, called a *ta*.

The weir is, as a rule, from 50 ft. to 60 ft. long and about 20 ft. wide, and the work is commenced at the crest of the rapid and continued down-stream. After a number of poles have been driven in, two horizontal timbers are lashed on, one below the other, after which more stakes are driven, it being easier to keep in line with guiding-timbers on top. A long and very heavy *totara* log, from 12 in. to 18 in. in diameter, is then lashed to the stakes at about low-water level, and further held in position by another row of stakes driven at an angle, the top of the stake finishing flush with the inside of the fence (fig. 6). The last post down-stream is clear of the heavy log, and only held by the top horizontal timber, so as not to interfere with the *poha* sliding up and down. This will be seen in the picture of the *pa-tuna* on Te Aute-mutu Rapid (see Plate XXVI).

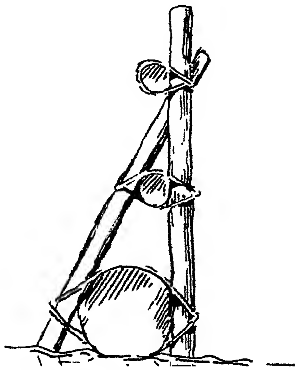


FIG. 6.—Section of large *pa-tuna*.

Considerable judgment was required in setting the fences at the proper angle against the current, and because of care in this matter, combined with good workmanship and position, some *pa-tuna* took more fish than others. The angle of fences was of the utmost importance, and always they ran into the current to a greater or less degree according to the arrangement of the stakes. If parallel with the current, or nearly so, few fish were intercepted, and if at too great an angle the eels escaped through the fence.

In a close arrangement of stakes, as the *pà-tuna* at Kauwae-roa (Plate XXV, figs. 1 and 2) a greater angle is given than in the *pa* at Te Aute-mutu (Plate XXVI), where the stakes are wider apart. The double fence was only for the purpose of intercepting more fish.

A bad architect superintending the construction of a *pa-tuna* was the object of much derision, and his failure was known throughout the district. An unsuccessful *pa* was always pulled down.

It is said that when eels travel up-stream they usually take the deepest and darkest water, taking advantage of every help, while lampreys keep close to the edge, especially in swift water. The log with its double row of stakes causes a sort of backwater right up the full length of the weir, and provides an easy passage for the wily *tuna*, which he is not slow to take advantage of. At the top of the *pa-tuna* a sloping rounded log, carefully smoothed, is fixed so as to turn the eels and cause them to be thrown back by the current, which carries them down into the *poha* before they regain shelter. At the foot of the weir two posts are driven in about 5 ft. away from the fences, one on either side, facing each other, and strongly braced to the main structure, their object being to hold the *poha* frame.

* I believe the name *kopuka* is peculiar to the Whanganui River natives, the names *kanuka* and *maru* being used for the wood (*Leptospermum ericoides*) in other places.

Usually there are sliding logs that work between these posts and the fences, held by the force of water, and also a rope that lifts or lowers them, together with the *poha* frame of the inverted Y pattern (see later), which is fixed to the *hinaki* in the manner before described (see fig. 7). These angles, being right across the current, are soon broken by driftwood, and, as a rule, have to be renewed or repaired annually. All the lashings used in the construction of the *pa* are of *aka* or *kareao* vines: no pegs or nails are ever used even in modern times. Usually the fences are lowest at the top of a rapid, gradually rising as they go down-stream.

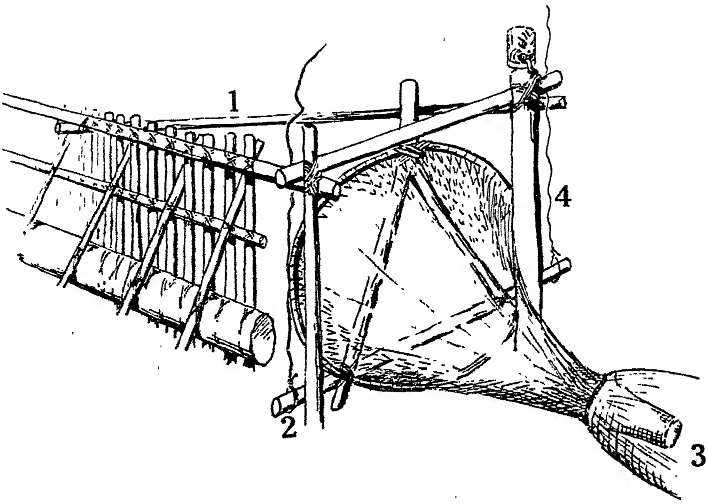


Fig. 7.—Attachment of the *poha*. 1, angle brace; 2, sliding timber used to raise and lower the *poha*; 3, *hinaki*; 4, ropes of twisted *kareao*.

The names of the parts of the *pa-tuna* are as follows: The stakes are called *pou;* the top horizontal timber, *uaua*, sometimes (I think, correctly) *huahua;* the second horizontal timber, *kaiwai;* the heavy bottom *totara* log, *huahua-kaiwai;* the angle stakes holding same, *noko;* the angle log at head of weir, *noko-panawai;* the return angle or wing at foot, *hoi;* the side posts holding same, *pou-riri* (sometimes *turu*); the sliding timber, *rango;* the same timber when fastened down, *huapae;* the water between the fences, *ihonui;* water outside of fences, *auroa*.

When a fresh is in evidence two baskets are placed in position on each side, one above the other, as in the case of the small *pa-tuna*. Of course, in this particular style of weir a great many eels must pass without being caught; but it would be quite impossible to net a large river in this manner thoroughly, owing to the logs and debris coming down. No doubt if the fences were to converge gradually they would be more effective in fishing, but they would be more liable to be destroyed, as the drift timbers would be caught and the weight of waters would soon be irresistible. However, a very large number of fish are taken, usually in April. The only time I saw this *pa-tuna* being worked upwards of half a ton of fish was taken out within twenty-four hours. This was during the *tuna-heke* migration.

A very large *pa-tuna* capable of holding eight or more *hinaki* is called *pa-tuna waharoa*. There is also another built on a zigzag principle, but neither of these have I seen, nor have I been able to obtain any description of them.

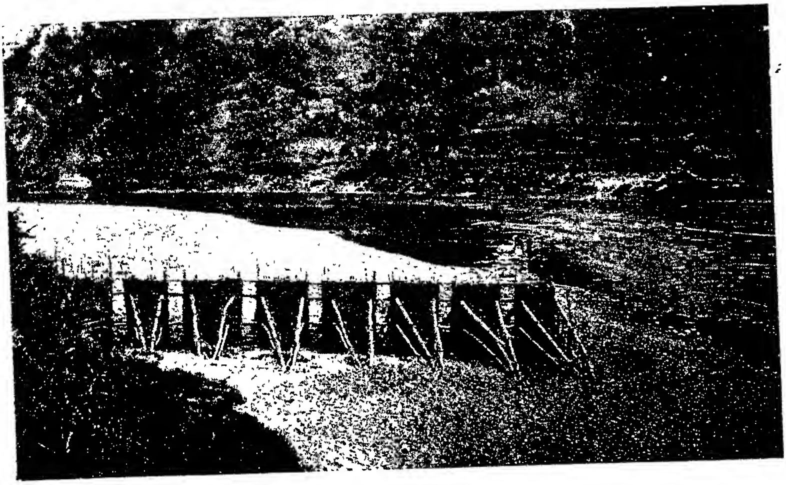


Fig. 1.—*Utu*, or lamprey-weir, at Parikino, Whanganui River, looking down-stream.

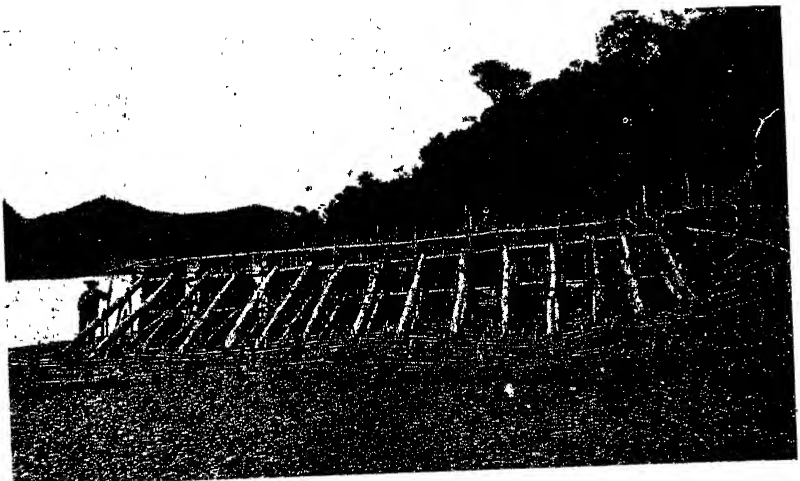
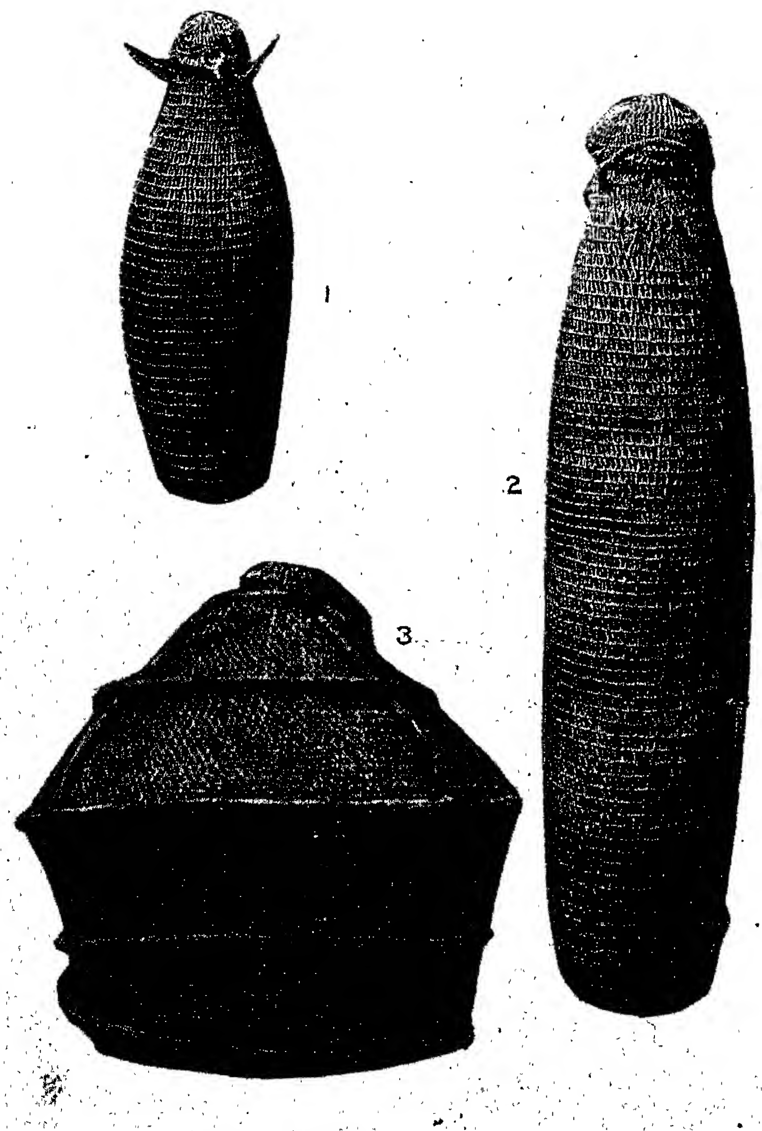
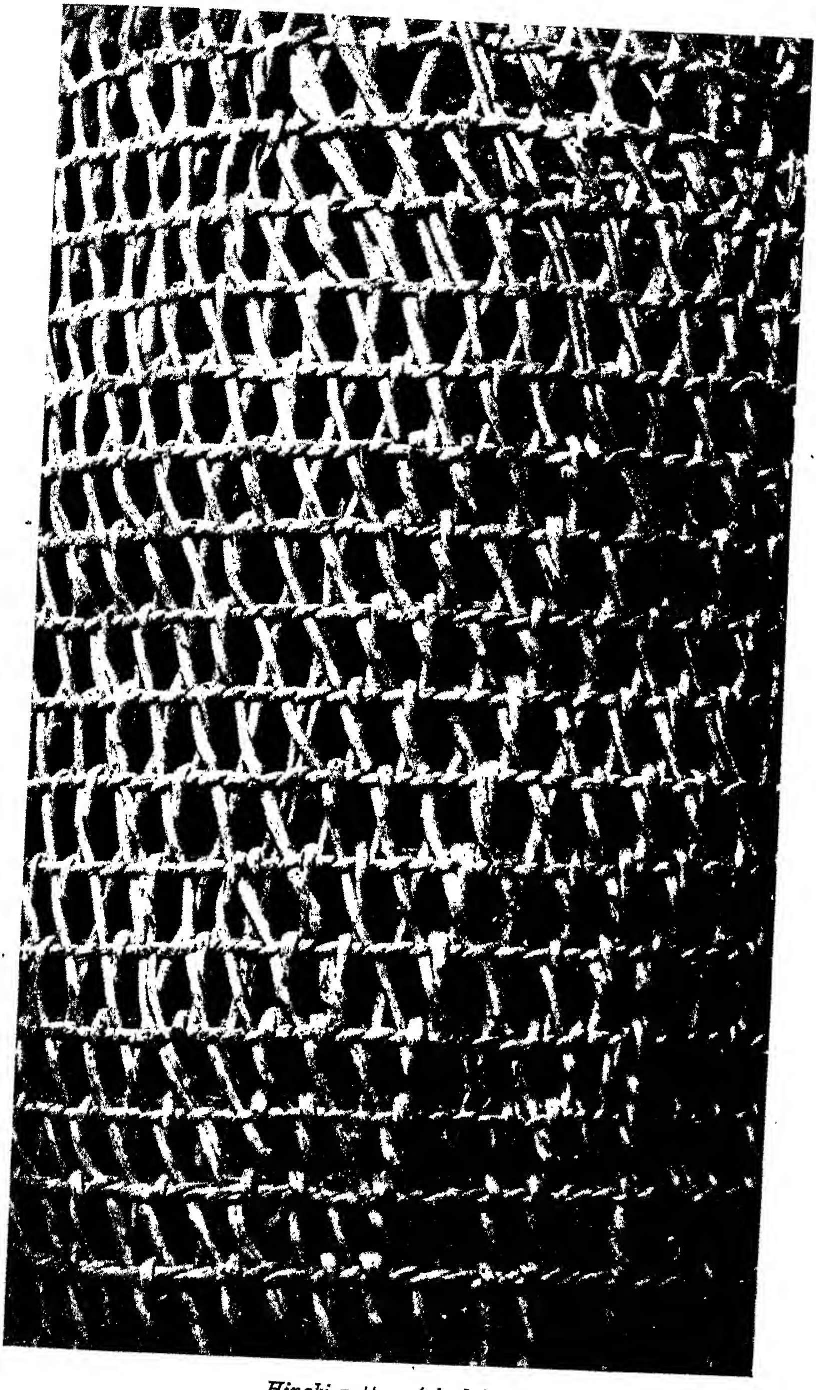


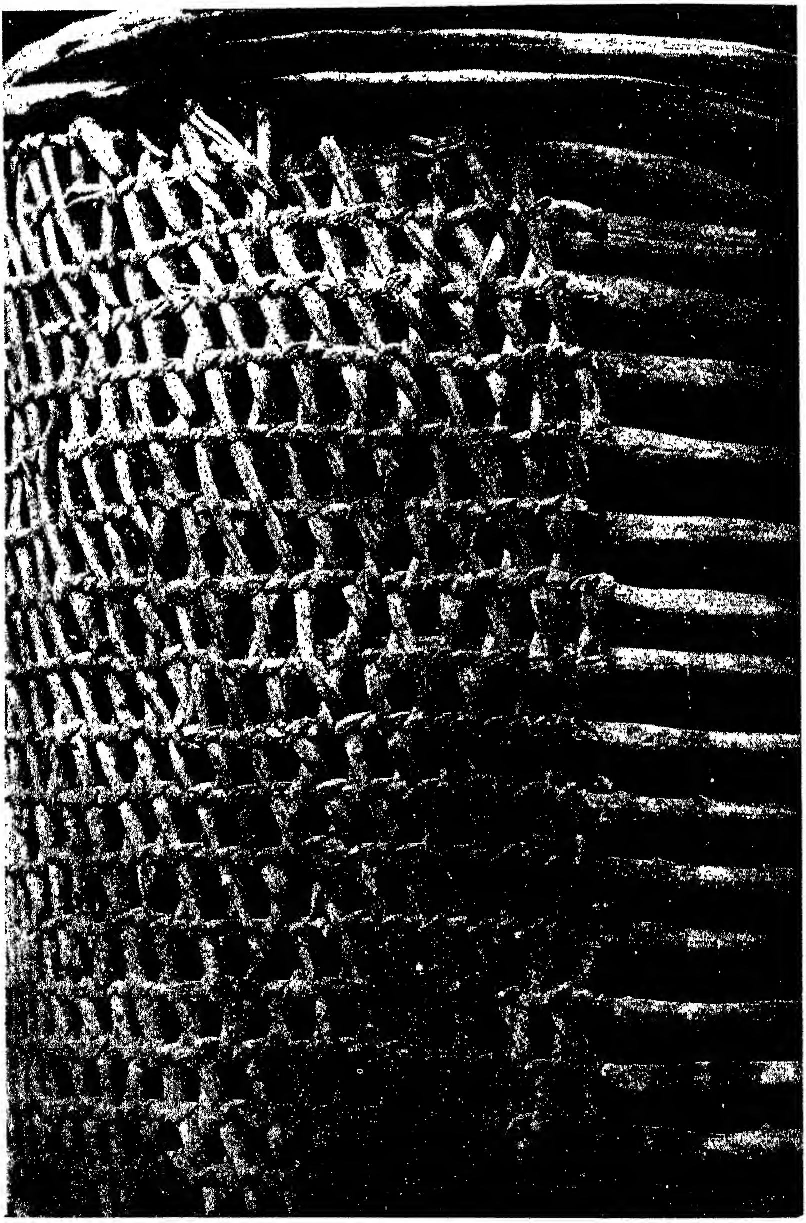
Fig. 2.—*Utu*, or lamprey-weir, at Parikino, Whanganui River, looking up-stream.



FIGS. 1, 2.—*Hinaki herehere* of different patterns.
FIG. 3.—*Korotete* lying under *whata tapu* (*tapu* storehouse) at Tawhata, Whanganui River.



Hinaki pattern (*ripeka*).



Hinaki pattern, showing arrangement of ribs.

The Utu, *a Weir for taking* Piharau (*Lampreys*).

This is built at right angles from the shore, and is built on dry ground by the side of a rapid, being only operated during flood-time (see Plate XXVII, figs. 1 and 2). It is like the *pa-tuna*, a fence built with closely driven stakes and horizontal cross-timbers, heavily matted or thatched on the up-river side, and strongly braced on both up- and down-stream sides. As the *utu* has to stand the full force of flood-waters, the bracing is exceptionally strong, upper and lower rows being thrown out at an angle from both horizontal stays on each side. Strong as they are, they seldom last more than a season. The photographs in Plate XXVII were taken at Parikino, Whanganui River, about five years ago, but of the original not a vestige now remains.

The fence is constructed so that the water is blocked at regular spacings, usually about 5 ft. wide, and can escape at alternate spaces of about 2 ft. The up-stream braces are fixed so as to lead the water towards the open parts, as is shown by the illustration. The matting is of bracken and *manuka* brush—principally bracken. Posts are usually fixed below the fence each side of the water-channel to hold the *poha*, the circular vine of which for this style of weir is generally attached to a forked piece of wood resembling an inverted Y, or to two pieces of straight wood spliced and tied together as an inverted V (see fig. 8). On the down-stream side a sort

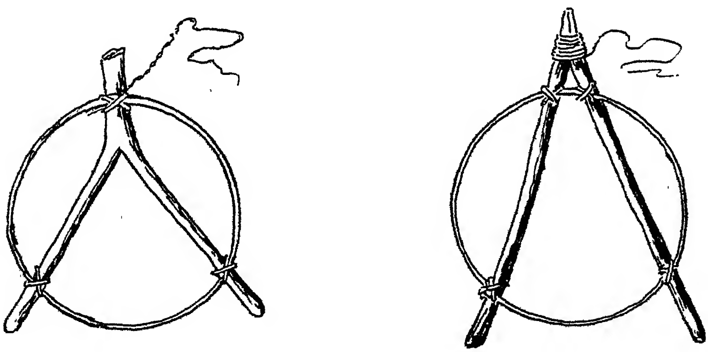


FIG. 8.—*Poha* frames for large *pa-tuna* or *utu*.

of floor is laid of *manuka* or fern, pressed down with thin *manuka* poles, which are held in position by pegs driven across them both ways.

The *piharau* congregate in the slack water immediately behind the wall part of the fence, but directly they attempt to go through the weir-opening they meet the full force of the swollen current and are thrown back into the nets.

Names of the *utu* parts are as follows: The stakes are called *pou;* the top horizontal pole, *huahua;* the second horizontal pole, *ngakau;* the braces, *noko;* the blocked part of fence, *pawai;* the opening, *ngutu;* the floor, *whariki;* the poles holding down the floor, *tapatu;* the crossed pegs holding down the poles, *tarapi*.

Hinaki.

Eel-baskets, or *hinaki*, as they are called, are of several shapes, sizes, and patterns. They are hard or flexible, regular in construction, and as a rule cone-shaped. They are small at each end, bulging out in the middle,

and are usually from 5 ft. to 6 ft. long and 18 in. to 2 ft. 6 in. in diameter at the widest part. One end is secured tight by a lid; the other returns inwards by a neat curve as a funnel, and finishes with an opening 3 in. or so in diameter about 1 ft. or 18 in. down the net. *Hinaki* were formerly chiefly constructed of aerial roots of *kiekie* (*Freycinetia Banksii*) steeped in water till pliable, and were light, strong, and flexible; but I am informed that the *akatea* vine (*Metrosideros albiflora*) and *aka tororaro* gave the best results both as regards strength and lasting qualities. The *pohue* vine (*Calystegia sepium*) was also used in the construction of the *hinaki*, but was called *aka korewa* when so used. Another vine, growing on stony plains, was also used for fine work and flexible springy baskets, but my informant was unable to remember the name. The *kiekie*, probably the most common, being the easiest to procure, was also the poorest, as

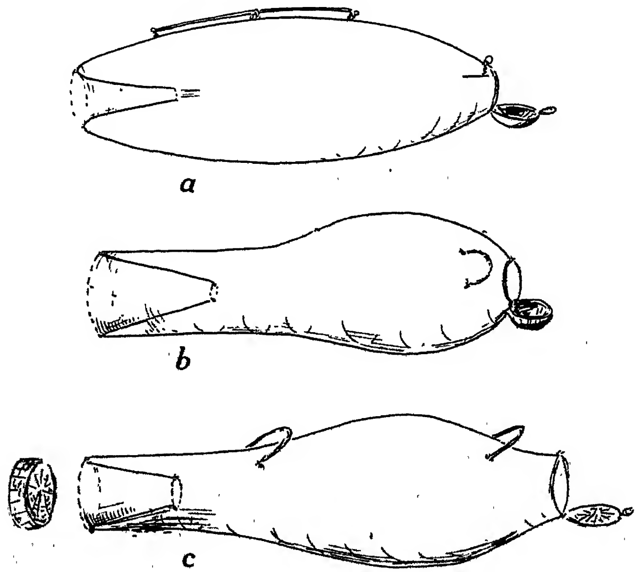
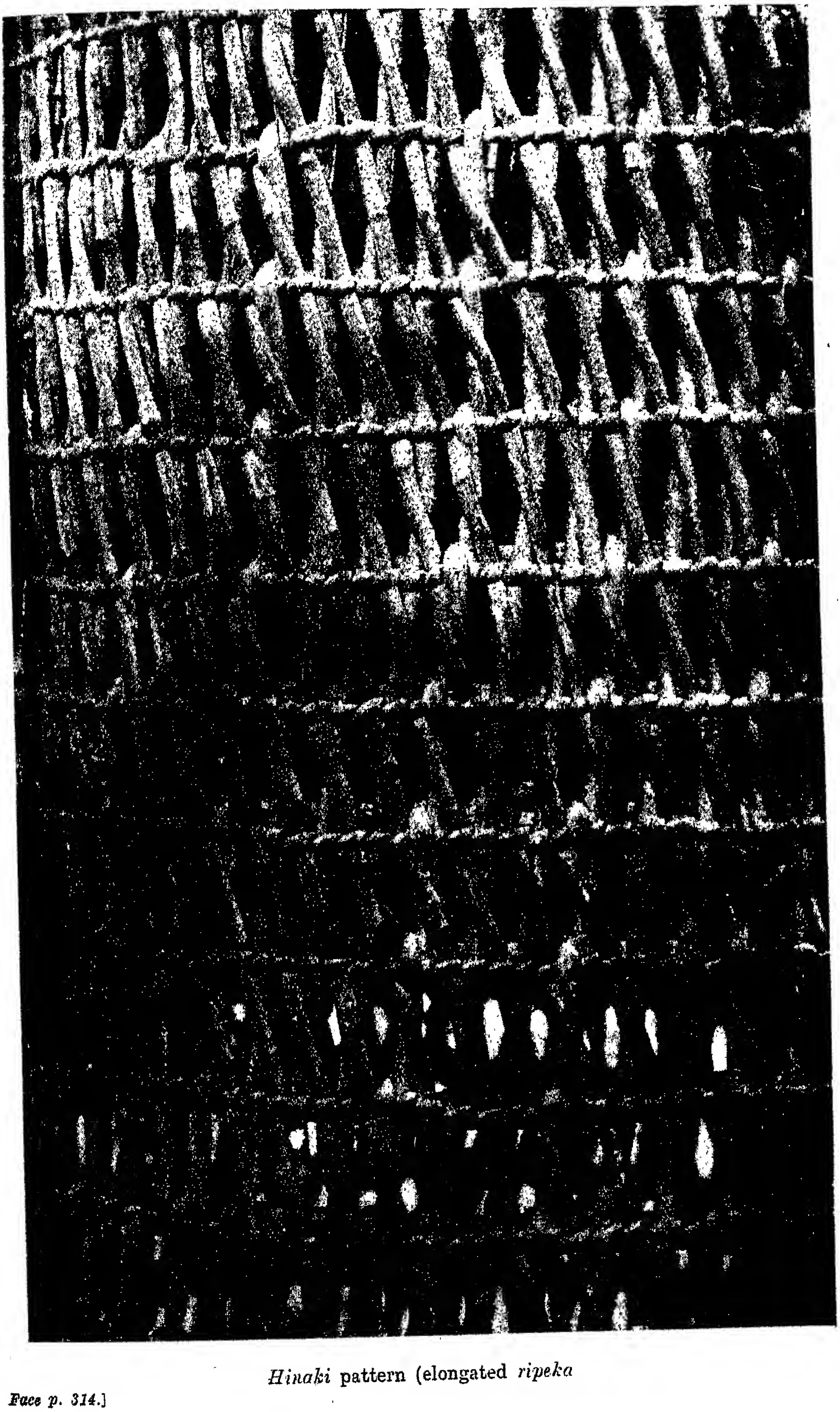


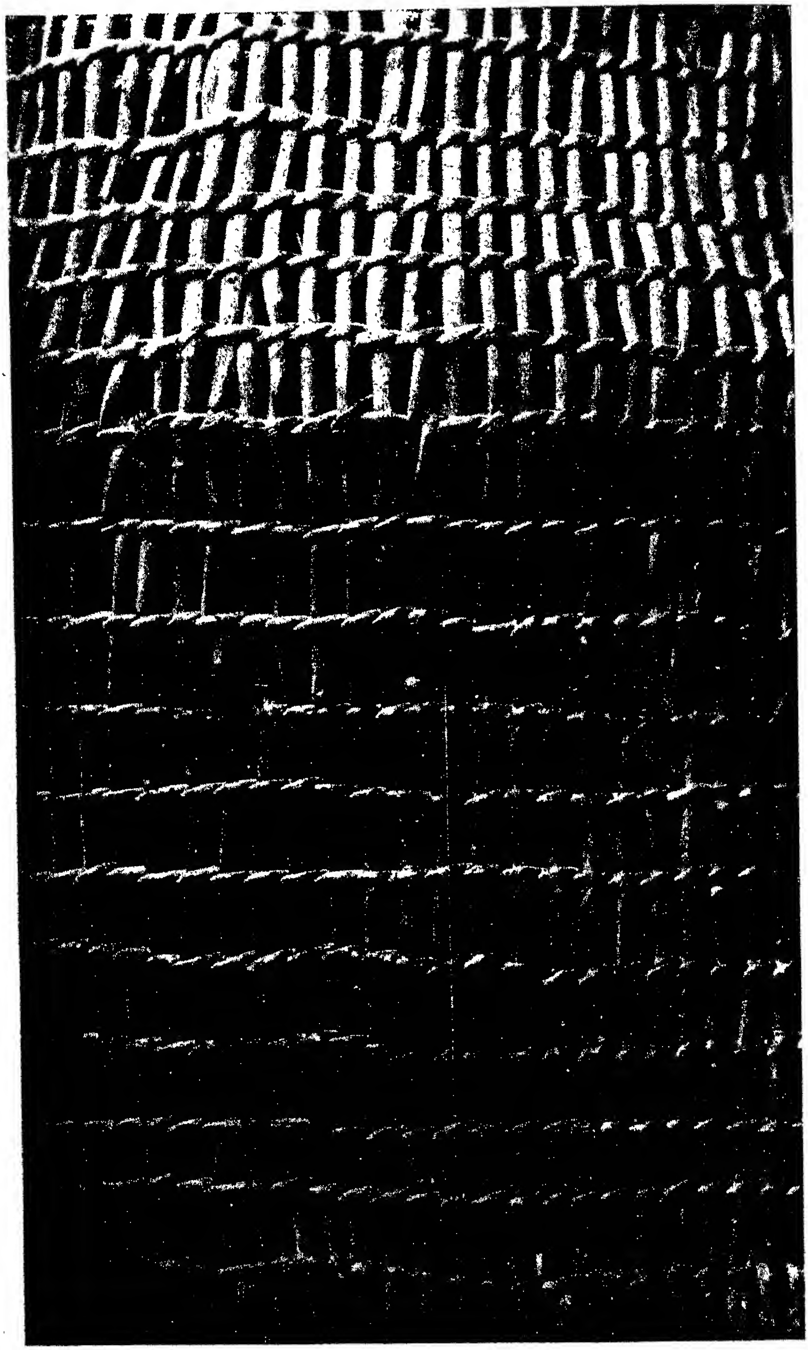
FIG. 9.—Types of *hinaki*: *a*, *hinaki herehere*; *b*, *hinaki tatairangi*; *c*, *hinaki waharoa* or *hinaki aranui*.

even with care it only lasted from five to seven years. Sometimes in a pattern called *pakipaki* thin *manuka* was used for the long strips which were laced on to *kareao* hoops with small vines, but I have never seen a basket made in that manner, although I understand they were common. In these modern days *kareao* and sometimes even wire netting are easily obtained substitutes, and it seems to me that the days of the old-time *hinaki* are numbered. Indeed, as European ideas and methods are gradually growing into favour and practice with the Maori, the old systems of obtaining food are gradually falling into disuse. Twenty-five years ago *pa-tuna* were common enough in almost every river and stream on the west coast of the North Island; now there are only two in the Whanganui, practically the home of the *pa-tuna*, and I do not think that farther south even one will be found.

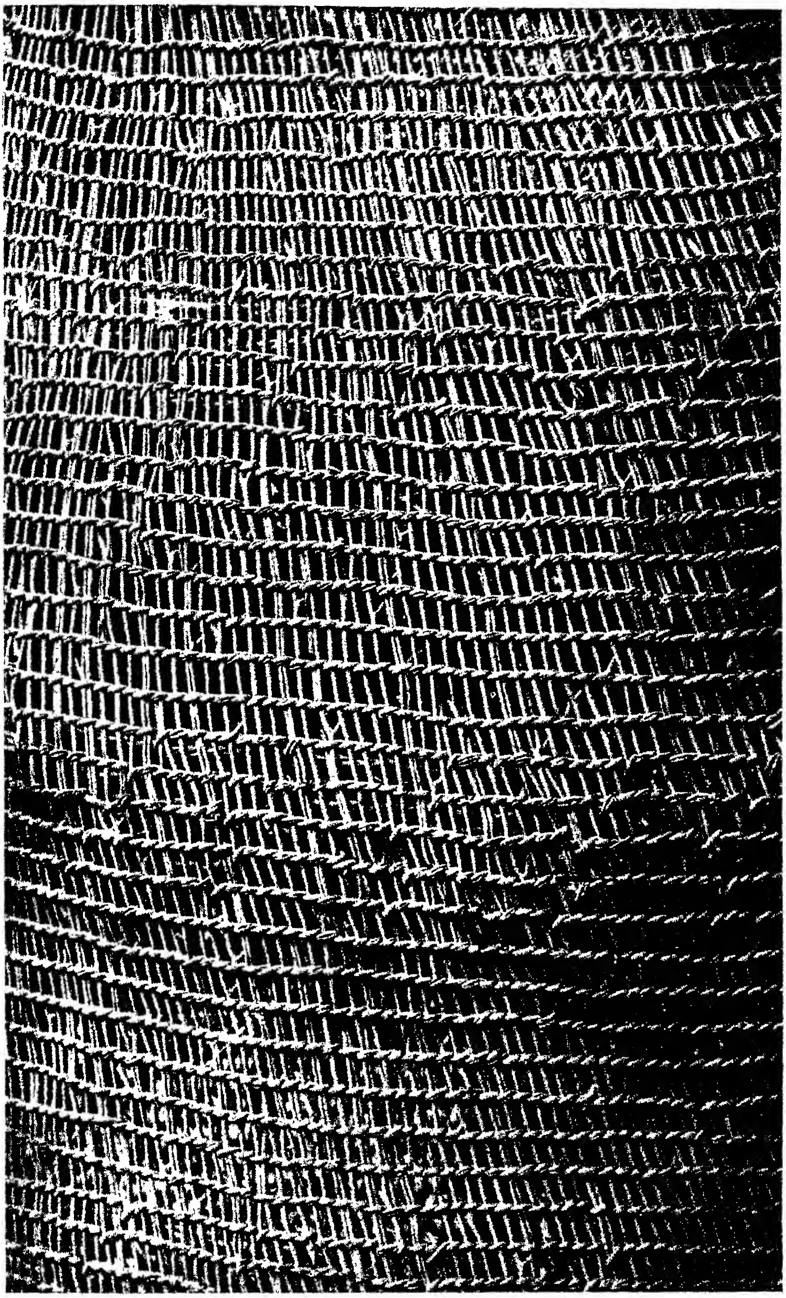


Hinaki pattern (elongated *ripeka*

Face p. 314.]



Hinaki pattern (*pakipaki* or *aurara*).



Hinaki pattern (pliable).

Hinaki kareao.

For the *hinaki* that was used for setting at *pa-tuna* the trap, or return part, was woven separately and laced on the *hinaki* afterwards, giving a continuation of the *poha* lead. Otherwise it was made in one piece. Sometimes for the bait-setting traps loose ends of vine ran together at the inner end of the net funnel, through which the eels could easily push their way but which securely blocked egress. The common shape was called *titika.* It was used entirely for catching *tuna-toke* with bait. In this as in the other shapes all the enlarging or reducing was done by adding or dropping strands. *Hinaki herehere* (fig. 9, *a*) was another style of trap used for baiting only. The bottle shape with parallel sides bulging at one end was called *pae*, sometimes *tatairangi* (fig. 9, *b*, and Plate XXVIII, figs. 1 and 2), and the large-mouthed *hinaki* for placing in the *pa-tuna* was called *whakapuwai*, and by some *waharoa* and *aranui* (fig. 9, *c*). This *hinaki* had usually a lid for both ends to hold eels if used as a storing-basket.

Puhara and *puwai* were baskets made without a trap end, used for keeping eels alive in the water.

A similar basket for holding live lamprey was called *korotete.* Occasionally these baskets were protected by vine rings tied on outside. A very fine specimen photographed by the writer, lying under a *whata tapu* (*tapu* storehouse) at Tawhata, about 120 miles up the Whanganui River, is manufactured in this manner (Plate XXVIII, fig. 3).

Hinaki-pitau, a very small trap of the *hinaki* pattern used for catching whitebait, was very closely woven of a thin vine called *kaii.** Another net for catching whitebait was called *hauwai.* It was in shape something like a huge scoop without the handle, and is now obsolete. As a boy I saw one of these used by a woman in the Rangitikei River, but that is the only one I have ever seen. It was made of a rush which I regret to say I have lost the name of. In the Whanganui district the whitebait is called *karohe* when the shoals first go up-stream in the spring.

Hinaki *and* Korotete *Patterns.*

There are at least three patterns, with their modifications and variations, used in weaving *hinaki* and *korotete*, one of the finest being called *ripeka.* It is rather complicated, but very strong (see Plate XXIX). The ribs run the whole length of the *hinaki* in a continuous spiral, and are placed about 1 in. apart. It will be seen from the accompanying photograph that the diagonal vines from left bottom corner to right top corner pass round the ribs at each intersection, passing under the two-ply twist that holds all together at the same time.

Plate XXX shows a modification of the same pattern, the twist round the rib taking place at intervals of between 2 in. and 3 in. Part of the basket-work was cut away in the original of this illustration in order to show the arrangement of the ribs, which gradually grow stronger towards the middle of the net.

Plate XXXI shows an elongated variation of the same pattern, and Plate XXXII the common oblong pattern called *pakipaki* and also *heaurara* (? *aurara*). In the illustration the ribs are shown close together, and

* The long, slender, and flexuous branches of the young plants of *matai* (*Podocarpus spicatus*), which young trees are called *kai* and *mai* by natives, were used in the manufacture of eel-pots. Possibly this is the material alluded to.

tied at irregular intervals by the long vines passing round them, but in many *hinaki* of a somewhat similar pattern they are arranged at intervals of about 6 in.

In Plate XXXIII is shown a flexible basket of a somewhat similar pattern to above, made of the *kaii** vine. The ribs are two-ply twist of the same material, but somewhat thicker, and are placed four or five close together within the space of 3 in. or 4 in., a similar distance being spaced without ribs. A basket constructed of this material is very fine, light, springy, and pliable, and must have taken a long time to manufacture.

Plate XXXIV shows the common basketware pattern made with split *kareao*. I have been unable to obtain a name for this basket except *hinaki kareao*. The Whanganui natives call this vine *karewau*. It is said that it usually takes an expert about a week to weave an ordinary *hinaki* about 5 ft. long of the *heaurara* pattern, which is certainly the simplest.

The parts of the *hinaki* are as follows: The ribs are called *potaka;* the ribs when continuing in a spiral, *whenu;* the lid, *taupoki;* the net or funnel-shaped entrance for *pa-tuna hinaki*, *akura* (also *kuao* and *te ure*); twisted vine handle at top, *popoia; manuka* handle at side, *kaharoa;* eye for securing lid, *popoki;* pin for same purpose, *taheke* (and also *kopiha*); the two-ply twist following round the ribs, *whatu;* the vine hinge, *toroaka;* outside protecting vines, *porowhita popoki.*

Tanning (Whakawahi).

Any one who has looked at *hinaki* closely will have noticed that some of the oldest types are sometimes black in colour. This is due to a tanning process that was formerly employed in order to lengthen the life of all *hinaki*, but which is now entirely omitted in the manufacture, and has not been used for many years.

Quantities of *maire* and *whinau* (*hinau*) bark were gathered, parcelled up, wrapped in leaves, and placed in an *umu* for prolonged steaming. A special trough, called *patua*, made of the inner bark taken from a large *totara* tree was provided. This bark was taken off in one sheet, first cut at both ends with a stone adze at the required length, and then prized off with a *maire* or *akeake* lever made especially for the purpose with a fire-hardened point. When a piece of bark was removed in this manner without split or flaw the ends were gradually softened by steam in an *umu* until they were quite pliable and could be bunched and tied.

This bark receptacle was used because it did not absorb the tannin as did a canoe or trough cut out of wood.

The softened pieces of *maire* bark were rubbed and worked by the hands until they crumbled away, and the *whinau*, which would not crumble, was broken as small as possible, and the mass was left in the *patua* just covered with water until the juices thoroughly impregnated the water. The bundles of vines intended for *hinaki* were placed in the dye and left for one or two nights, according to the thickness and texture of the bundles so treated. The process was called *whakawahi*.

* Some natives give this vine as the *kii*, and say it is found near the sea; but I am unable to give its botanical name.

ART. XXXII.—*On certain Tripolar Relations: Part III.*

By E. G. HOGG, M.A., F.R.A.S., Christ's College, Christchurch.

[*Read before the Philosophical Institute of Canterbury, 1st November, 1916; received by Editors, 22nd December, 1917; issued separately, 24th June, 1918.*]

THE equation of the circle of radius ρ having its centre at the point O, whose trilinear co-ordinates are $(\alpha_0, \beta_0, \gamma_0)$, is

$$U \equiv a\alpha_0 X + b\beta_0 Y + c\gamma_0 Z - 2RS_0 - 2\triangle\rho^2 = o \quad \text{(i)}$$

Let d be the distance of O from H, the centre of the circle ABC. If U pass through H, then

$$R^2 (a\alpha_0 + b\beta_0 + c\gamma_0) - 2RS_0 - 2\triangle d^2 = o\,;$$

i.e.,
$$2RS_0 = 2\triangle(R^2 - d^2):$$

hence U may be written

$$a\alpha_0 X + b\beta_0 Y + c\gamma_0 Z = 2\triangle(R^2 + \rho^2 - d^2) \quad \text{(ii)}$$

If the circle U cut the circle ABC at the angle θ, then $R^2 + \rho^2 - d^2 = 2R\rho\cos\theta$, whence

$$U \equiv a\alpha_0 X + b\beta_0 Y + c\gamma_0 Z - abc\,\rho\cos\theta = o \quad \text{(iii)}$$

The equations of the circles of radius ρ and centre $(\alpha_0\beta_0\gamma_0)$ touching the circle ABC internally and externally are respectively

$$a\alpha_0 X + b\beta_0 Y + c\gamma_0 Z - abc\,\rho = o$$
$$a\alpha_0 X + b\beta_0 Y + c\gamma_0 Z + abc\,\rho = o,$$

the trilinear co-ordinates of the point of contact being

$$\frac{R}{R \pm \rho}\left[\alpha_0 \pm \rho\cos A,\ \beta_0 \pm \rho\cos B,\ \gamma_0 \pm \rho\cos C\right],$$

the negative sign being taken for internal contact.

If U reduce to a point-circle, (ii) then takes the form

$$a\alpha_0 X + b\beta_0 Y + c\gamma_0 Z = (a\alpha_0 + b\beta_0 + c\gamma_0)(R^2 - d^2)\,;$$

i.e.,
$$a\alpha_0 (X + d^2 - R^2) + b\beta_0 (Y + d^2 - R^2) + c\gamma_0 (Z + d^2 - R^2) = o.$$

Let $X = \rho_1^2$, $Y = \rho_2^2$, $Z = \rho_3^2$, and let the radii HA, HB, HC subtend at O the angles λ, μ, ν respectively; we then have

$$a\alpha_0\rho_1\cos\lambda + b\beta_0\rho_2\cos\mu + c\gamma_0\rho_3\cos\nu = o \quad \text{(iv)}$$

The following particular cases of (iv) are of interest. For the orthocentre, in-centre, centroid, and symmedian point respectively

$$\sin A \cos\lambda + \sin B \cos\mu + \sin C \cos\nu = o$$

$$\cos\frac{A}{2}\cos\lambda + \cos\frac{B}{2}\cos\mu + \cos\frac{C}{2}\cos\nu = o$$

$$m_1\cos\lambda + m_2\cos\mu + m_3\cos\nu = o$$

$$am_1\cos\lambda + bm_2\cos\mu + cm_3\cos\nu = o,$$

where m_1, m_2, and m_3 are the medians of the triangle ABC.

If O be either of the two points whose pedal triangles are equiangular, then, since for these points $a\rho_1 = b\rho_2 = c\rho_3$,

$$\alpha_o \cos\lambda + \beta_o \cos\mu + \gamma_o \cos\nu = o.$$

If O be the focus of a conic inscribed in the triangle ABC, then the equation of the conic is

$$a\sqrt{X_o\alpha_o\alpha} + b\sqrt{Y_o\beta_o\beta} + c\sqrt{Z_o\gamma_o\gamma} = o.$$

Comparing this with the equation of the maximum inscribed ellipse, $\sqrt{a\alpha} + \sqrt{b\beta} + \sqrt{c\gamma} = o$, we have $aX_o\alpha_o = bY_o\beta_o = cZ_o\gamma_o$, whence

$$\frac{\cos\lambda}{AO} + \frac{\cos\mu}{BO} + \frac{\cos\nu}{CO} = o.$$

For the Brocard ellipse this gives

$$\frac{\cos\lambda}{BC\,.\,AO} + \frac{\cos\mu}{CA\,.\,BO} + \frac{\cos\nu}{AB\,.\,CO} = o.$$

Let U^1 be the result of substituting in U the co-ordinates (X^1, Y^1, Z^1) for (X, Y, Z). Suppose a circle of radius ρ^1 concentric with U to pass through the point $(X^1Y^1Z^1)$, then

$$U^1 = a\alpha_oX^1 + b\beta_oY^1 + c\gamma_oZ^1 - 2RS_o - 2\Delta\rho^2\ ,$$

$$O = a\alpha_oX^1 + b\beta_oY^1 + c\gamma_oZ^1 - 2RS_o - 2\Delta\rho^{1\,2}$$

$$\therefore U^1 = 2\Delta(\rho^{1\,2} - \rho^2) = 2\Delta t^{1\,2},$$

where t^1 is the length of the tangent from $(X^1Y^1Z^1)$ to the circle $U = O$.

Let t_1, t_2, and t_3 be the lengths of the tangents to the circle U from A, B, C respectively: then

$$2\Delta t_1^2 = b\beta_oc^2 + c\gamma_ob^2 - 2\Delta(R^2 - d^2 + \rho^2);$$

i.e., $$2\Delta(t_1^2 + R^2 - d_2 + \rho^2) = b\beta_oc^2 + c\gamma_ob^2.$$

We have $X_o = t_1^2 + \rho^2$, whence, if OH subtend at A, B, and C the angles θ, ϕ, ψ respectively,

$$abc\,\rho_1\cos\theta = b\beta_oc^2 + c\gamma_ob^2$$

$$abc\,\rho_2\cos\phi = a\alpha_oc^2 + c\gamma_oa^2$$

$$abc\,\rho_3\cos\psi = a\alpha_ob^2 + b\beta_oa^2$$

$$2\Delta = a\alpha_o + b\beta_o + c\gamma_o.$$

Eliminating $a\alpha_0$, $b\beta_0$, $c\gamma_0$ we have

$$\begin{vmatrix} 2R\rho_1 \cos\theta & o & c^2 & b^2 \\ 2R\rho_2 \cos\phi & c^2 & o & a^2 \\ 2R\rho_3 \cos\psi & b^2 & a^2 & o \\ 1 & 1 & 1 & 1 \end{vmatrix} = o,$$

which reduces to the relation

$$a\rho_1 \cos A \cos\theta + b\rho_2 \cos B \cos\phi + c\rho_3 \cos C \cos\psi = 2\,\Delta.$$

From the equations

$$\frac{a\rho_1 \cos\theta}{bc} = \frac{\beta_0}{b} + \frac{\gamma_0}{c},\quad \frac{b\rho_2\cos\phi}{ca} = \frac{\gamma_0}{c} + \frac{\alpha_0}{a},\quad \frac{c\rho_3\cos\psi}{ab} = \frac{\alpha_0}{a} + \frac{\beta_0}{b},$$

we see that if O lie on the trilinear polar of the symmedian point

$$BC^2\, AO\cos\theta + CA^2\, BO\cos\phi + AB^2\, CO\cos\psi = o.$$

Solving for α_0, β_0, γ_0 from the above equations, and substituting in he equation of the circle ABC, we obtain the relation

$$BC\sqrt{OA\cos\theta} + CA\sqrt{OB\cos\phi} + AB\sqrt{OC\cos\psi} = o$$

for any point O on the circle.

If t_0 be the length of the tangent to any circle from the middle point of BC, then

$$2\,\Delta\, t_2^2 = a\alpha_0 c^2 + c\gamma_0 a^2 - 2\,(RS_0 + \Delta\,\rho^2)$$
$$2\,\Delta\, t_3^2 = a\alpha_0 b^2 + b\beta_0 a^2 - 2\,(RS_0 + \Delta\,\rho^2)$$
$$2\,\Delta\, t_0^2 = a\alpha_0 m_1^2 + \frac{a^2}{4}(b\beta_0 + c\gamma_0) - 2\,(RS_0 + \Delta\,\rho^2)$$

where m_1 is the median drawn through A.

Hence
$$2\,\Delta\,(t_2^2 + t_3^2 - 2t_0^2)$$
$$= a\alpha_0\,(b^2 + c^2 - 2m_1^2) + \frac{a^2}{2}(b\beta_0 + c\gamma_0)$$
$$= \frac{a^2}{2} 2\,\Delta;$$

i.e.,
$$t_2^2 + t_3^2 = 2t_0^2 + \frac{a^2}{2},$$

an extension of the Theorem of Apollonius.

If U be the polar circle of the triangle ABC, then

$$U \equiv \tan AX + \tan BY + \tan CZ - 2\,\Delta = o$$
$$\therefore 2\,\Delta\, t_2^2 = \kappa\,(c^2 \tan A + a^2 \tan C - 2\,\Delta),$$

where
$$\kappa = 4R^2 \cos A \cos B \cos C,$$

which reduces to $t_2^2 = ca\cos B$. Also $t_3^2 = ab\cos C$, hence $t_2^2 + t_3^2 = a^2$.

If in the triangle ABC the angle A be obtuse, then the sum of the squares of the tangents to the polar circle from B and C is BC^2.

If $U = o$ pass through the point $(X_1 Y_1 Z_1)$, then the locus of O $(\alpha_0\beta_0\gamma_0)$ is the circle

$$V \equiv a\alpha X_1 + b\beta Y_1 + c\gamma Z_1 - 2RS - 2\,\Delta\,\rho^2 = o.$$

If t_1, t_2, t_3 be the lengths of the tangents to the circle V from A, B, C respectively, then $X_1 = t_1^2 + \rho^2$, $Y_1 = t_2^2 + \rho^2$, $Z = t_3^2 + \rho^2$, and the equation of the circle takes the form

$$V \equiv (t_1^2 a\alpha + t_2^2 b\beta + t_3^2 c\gamma)(a\alpha + b\beta + c\gamma) - abc\,S = o.$$

If V touch the circle ABC, then expressing that the radical axis of the two circles is a tangent to S we have

$$at_1 \pm bt_2 \pm ct_3 = o,$$

from which we obtain Ptolemy's theorem if we suppose V to reduce to a point-circle.

This extension of Ptolemy's theorem may be proved geometrically as follows:—

Suppose the circle V to touch the circle ABC at the point O on the arc BC, and let AO, BO, CO meet V in the points D, E, F respectively; then $t_2^2 = \text{BO} \,.\, \text{BE}$ and $t_3^2 = \text{CO} \,.\, \text{CF}$. Also $\dfrac{\text{OE}}{\text{OF}} = \dfrac{\text{OB}}{\text{OC}}$, and therefore $\dfrac{\text{BE}}{\text{CF}} = \dfrac{\text{OB}}{\text{OC}}$, hence $t_2^2 : t_3^2 = \text{OB}^2 : \text{OC}^2$;

i.e.,
$$t_1 : t_2 : t_3 = \text{OA} : \text{OB} : \text{OC}.$$

By Ptolemy's theorem BC . OA = AC . OB + AB . OC;

i.e.,
$$at_1 = bt_2 + ct_3.$$

If t be the length of the tangent to the circle $V = o$ from any point P $(\alpha_0\beta_0\gamma_0)$, then

$$2\,\Delta\, t^2 = a\alpha_0 t_1^2 + b\beta_0 t_2^2 + c\gamma_0 t_3^2 - 2\text{RS}_0.$$

For the circle BPC, $t = t_2 = t_3 = o$.

Consider now the circles BPC, CPA, APB. We have

$$a\alpha_0 t_1^2 = b\beta_0 t_2^2 = c\gamma_0 t_3^2 = 2\text{RS}_0.$$

Hence
$$\frac{a\alpha_0 + b\beta_0 + c\gamma_0}{2\text{RS}_0} = \frac{1}{t_1^2} + \frac{1}{t_2^2} + \frac{1}{t_3^2}$$

i.e.,
$$\frac{\Delta}{t_1^2} + \frac{\Delta}{t_2^2} + \frac{\Delta}{t_3^2} = \frac{\Delta}{\text{R}^2 - d^2}$$

where d is the distance of P from the circum-centre of the triangle ABC.

If P be the symmedian point of the triangle ABC, then $at_1 = bt_2 = ct_3$: if G be the centroid of the triangle $t_1^2 = t_2^2 = t_3^2 = \frac{1}{3}\Sigma(a^2)$.

If the circle V reduce to a point P_1 whose tripolar co-ordinates are $(X_1Y_1Z_1)$ we have

$$X_1 a\alpha + Y_1 b\beta + Z_1 c\gamma = 2\text{RS}.$$

For a point-circle at P_2 $(X_2Y_2Z_2)$

$$X_2 a\alpha + Y_2 b\beta + Z_2 c\gamma = 2\text{RS}.$$

Hence the radical axis of the pair of circles is

$$(X_1 - X_2)\,a\alpha + (Y_1 - Y_2)\,b\beta + (Z_1 - Z_2)\,c\gamma = o.$$

If P_1, P_2 be inverse points determined by the equations $\frac{X}{l} = \frac{Y}{m} = \frac{Z}{n}$, then $\frac{X_1 - X_2}{l} = \frac{Y_1 - Y_2}{m} = \frac{Z_1 - Z_2}{n} = \kappa_1 - \kappa_2$, where κ_1 and κ_2 are the roots of the equation $\kappa^2 \, [\Sigma \, (a^2 l^2) - 2 \, \Sigma \, (bc \cos Amn]$

$$- 2\kappa \, abc \, [\Sigma \, (a \cos Al)] + a^2 b^2 c^2 = o.$$

Hence the equation of the line bisecting perpendicularly the above pair of inverse points is

$$la\alpha + mb\beta + nc\gamma = o.$$

The two points whose pedal triangles are equilateral are determined by the equations $a^2 X = b^2 Y = c^2 Z$. Hence these points are equidistant from the line $\frac{\alpha}{a} + \frac{\beta}{b} + \frac{\gamma}{c} = o$, which is therefore perpendicular to the Brocard diameter $\Sigma \, [a^2 (b^2 - c^2) \, X] = o$, on which the points lie.

The two points whose distances from A, B, C are proportional respectively to a, b, c are given by the equations $\frac{X}{a^2} = \frac{Y}{b^2} = \frac{Z}{c^2}$: they therefore lie on Euler's line, $\Sigma \, [(b^2 - c^2) \, X] = o$, and are equidistant from the line $a^3 \alpha + b^3 \beta + c^3 \gamma = o$.

Let two pairs of inverse points be determined by the equations $\frac{X}{l_1} = \frac{Y}{m_1} = \frac{Z}{n_1}$ and $\frac{X}{l_2} = \frac{Y}{m_2} = \frac{Z}{n_2}$; the centre of the circle through them will be determined by the equations

$$l_1 a\alpha + m_1 b\beta + n_1 c\gamma = o$$
$$l_2 a\alpha + m_2 b\beta + n_2 c\gamma = o,$$

whence $\quad a\alpha : b\beta : c\gamma = m_1 n_2 - m_2 n_1 : n_1 l_2 - n_2 l_1 : l_1 m_2 - l_2 m_1,$

and the equation of the circle will be

$$(m_1 n_2 - m_2 n_1) \, X + (n_1 l_2 - n_2 l_1) \, Y + (l_1 m_2 - l_2 m_1) \, Z = o.$$

The two pairs of points will lie respectively on the diameters

$$(m_1 - n_1) \, X + (n_1 - l_1) \, Y + (l_1 - m_1) \, Z = o$$
$$(m_2 - n_2) \, X + (n_2 - l_2) \, Y + (l_2 - m_2) \, Z = o.$$

We now proceed to find the equation in tripolar co-ordinates of the inverse of the circle $U \equiv o$ with respect to S, the circum-circle of the triangle ABC.

$$U \equiv lX + mY + nZ - h^2 = o$$
$$S \equiv a \cos AX + b \cos BY + c \cos CZ - abc = o.$$

Let P be any point on U and Q its inverse. Let (X, Y, Z), (X^1, Y^1, Z^1) be the tripolar co-ordinates of P and Q respectively, then

$$\frac{X}{X^1} = \frac{Y}{Y^1} = \frac{Z}{Z^1} = \frac{HP^2}{R^2},$$

where H is the circum-centre.

Hence $\qquad HP^2 \, (lX^1 + mY^1 + nZ^1) = h^2 R^2.$

The equation of the circle of radius HP concentric with the circum-circle is

$$a \cos AX + b \cos BY + c \cos CZ - 2 \triangle R = 4RHP^2 \sin A \sin B \sin C.$$

Hence

$$HP^2 (a \cos AX^1 + b \cos BY^1 + c \cos CZ^1 - 2 \triangle R) = 2 \triangle R^3.$$

Eliminating HP^2, the equation of the inverse of U becomes

$$\frac{a \cos AX + b \cos BY + c \cos CZ - 2 \triangle R}{lX + mY + nZ} = \frac{2 \triangle R}{h^2}$$

or $$h^2 (S + 2 \triangle R) = 2 \triangle R (h^2 + U);$$

i.e., $$h^2 S - 2 \triangle RU = o.$$

The equation of the circle which is the inverse of the line $lX + mY + nZ - h^2 = o$ takes the same form as the above, subject to the condition $l + m + n = o$.

The equation of the circle which is the inverse with respect to the circle ABC of the line $p\alpha + q\beta + r\gamma = o$ is

$$\begin{aligned} &aX \{p \cos 2A + q \cos (A - B) + r \cos (C - A)\} \\ &+ bY \{p \cos (A - B) + q \cos 2B + r \cos (B - C)\} \\ &+ cZ \{p \cos (C - A) + q \cos (B - C) + r \cos 2C\} \\ &= abc\, (p \cos A + q \cos B + r \cos C). \end{aligned}$$

The equation of the circle which is the inverse with respect to the circle ABC of the line $\frac{\alpha}{a} + \frac{\beta}{b} + \frac{\gamma}{c} = o$ is

$$a \cos (A - \omega)\, X + b \cos (B - \omega)\, Y + c \cos (C - \omega)\, Z = abc \cos \omega,$$

where ω is the Brocard angle of the triangle ABC.

PROCEEDINGS

PROCEEDINGS

OF THE

NEW ZEALAND INSTITUTE, 1917.

FIFTEENTH ANNUAL MEETING.

WELLINGTON, 29TH AND 30TH JANUARY, 1918.

THE annual meeting of the New Zealand Institute Board of Governors was held in the Dominion Museum Library on Tuesday, the 29th January, 1918, at 10 a.m.

Present: Professor Benham, President (in the chair); Professors Kirk, Marshall, Segar, and A. P. W. Thomas; Drs. Cockayne, Hilgendorf, and Allan Thomson; Messrs. Aston, Birks, Eliott, Ewen, Hill, Hogben, Parr, and G. M. Thomson.

The Secretary called the roll, and the President apologized for the absence of Professor Chilton, who was laid aside by illness.

Presidential Address.—The President then delivered his presidential address (see p. 338).

A hearty vote of thanks to the President for his address was moved by Mr. Hill, seconded by Professor Marshall, and carried. A Committee consisting of the President and Dr. Hilgendorf was, on the motion of Professor Kirk, seconded by Professor Thomas, appointed to consider and report on points in the President's address which call for action, to report to this meeting.

The Incorporated Societies' Annual Reports and Balance-sheets for their last financial years were laid on the table. Received.

The Report of the Standing Committee was considered clause by clause and adopted (Appendices A, B, C to be discussed later).

REPORT OF THE STANDING COMMITTEE FOR THE YEAR ENDING 31ST DECEMBER, 1917.

Five meetings of the Committee have been held during the year, the attendance being as follows: Dr. Cockayne, 2; Professor Easterfield, 5; Professor Kirk, 5; Dr. Thomson, 5; and Mr. Aston, 5.

Hector Memorial Fund Award.—No details of the presentation to Sir E. Rutherford have yet been received, although medal and prize were sent to England over a year ago through the Department of Internal Affairs and the Public Trustee respectively. The 1917 medal was publicly presented to Dr. C. Chilton at a meeting of the Philosophical Institute of Canterbury held on the 1st August, 1917. The Public Trustee has been nstructed to forward a cheque for the amount of the prize to Dr. Chilton.

Hutton Memorial Medal for 1917.—The medal was publicly presented to Dr. P. Marshall by His Excellency the Governor-General when on a visit to Wanganui in September, but no details have yet been received.

Jubilee of the Institute.—This year the New Zealand Institute completes its fiftieth year of activity. The Standing Committee recommends that, owing to the war, any recognition of the Jubilee be postponed until a more convenient season.

War Roll of Honour.—The Hon. Secretary has collected data from the incorporated societies for the preparation of a Roll of Honour to be published at some future date.

Volume 48, Transactions and Proceedings, N.Z. Institute.—This was issued in bulk to the incorporated societies in October, 1916, but Parliament having adjourned, a copy was not laid on the table of the House of Representatives until the 3rd July, 1917, and on that of the Legislative Council on the 5th July, 1917.

Distribution of Transactions.—The Standing Committee regrets that it was not found possible to distribute the *Transactions* volume 49 to each member by post from Wellington.

Distribution of Excess of Back Numbers of Transactions.—A few applications from libraries have been received for partial sets, and the following should be added to the list of those who have received them:—

Department of Agriculture Library, Wellington.
Technical College, Wanganui.
Fiji Museum, Suva.
Kuaotunu Public Library, Kuaotunu.

Mailing-list.—The following has been added to the mailing-list, and will in future receive the *Transactions* as published:—

American Journal of Science (Editors), Yale University, New Haven, Connecticut, U.S.A.

Resolutions of the Standing Committee—Banking Account: It was resolved that only the following be authorized to operate on the Institute's banking accounts: viz., the Hon. Treasurer, the Hon. Secretary, and Professor Easterfield. This to continue in force until revoked in writing.

Major Broun's Bulletin.—It was resolved that 400 copies of Major Broun's bulletin be printed.

National Efficiency and Research.—A most important feature in the history of the New Zealand Institute was the appeal from the Government National Efficiency Board for advice on the relation of scientific and industrial research to national efficiency. On the 7th June, 1917, a letter from the Chairman of the National Efficiency Board (Mr. William Ferguson) was received by the Standing Committee, asking its advice, and suggesting that the Committee should hold a special meeting to consider the following resolution forwarded by the National Efficiency Board:—"*Scientific and Industrial Research:* Resolved, That the Standing Committee of the New Zealand Institute be asked to advise the Chairman on the matter, with power to consult other scientific men technologists in the Dominion, and the Committee be requested to hold its first meeting on a date when, if possible, the Senate of the University will be in Wellington, so that those members of that body who are members of the Committee can attend its deliberations."

The Standing Committee referred the matter to the President of the Institute (Professor Benham, Dunedin), asking for authority to resolve itself into a committee with power to co-opt members outside those already on the Board of Governors, to receive suggestions from the incorporated societies and other bodies and persons interested in any scheme of organization of research and industry, to collect these suggestions received, and to prepare a scheme for submission to the full Board of Governors.

A confidential report on the organization of scientific and industrial research, by Dr. J. Allan Thomson, dated the 20th July, 1916, to the Hon. the Minister of Internal Affairs, was used as a basis of discussion, with the consent of the Hon. the Minister, who supplied a limited number of typed copies for private circulation. At a further meeting on the 5th July the Standing Committee received a letter from the President empowering the Committee to proceed in the direction desired. The Committee therefore co-opted the following: Dr. C. E. Adams, Mr. D. C. Bates, Dr. C. A. Cotton, Mr. William Ferguson, Dr. Frengley, Mr. F. W. Furkert, Mr. W. H. Holmes, Mr. H. H. Jackson, Mr. J. C. Lewis, Dr. J. S. Maclaurin, Mr. W. B. Montgomery, Mr. P. G. Morgan, Mr. W. H. Morton, Mr. Evan Parry, Dr. C. J. Reakes, and Mr. E. Phillips Turner.

Certain bodies were also asked to select someone to represent them on the Committee, and the following were so elected: The Industrial Corporation of New Zealand appointed its president, Mr. F. J. Evans; the Workers' Education Association of

Wellington appointed Professor T. Hunter; and the Council of Education appointed Mr. George Hogben to represent it on the Committee.

The name of this Committee adopted was the New Zealand Institute's Scientific and Industrial Research Committee. Mr. George Hogben, C.M.G., was unanimously appointed permanent Chairman, and seven meetings were held in September, October, November, and December, the attendance being as follows: Mr. George Hogben, 7; Dr. Adams, 6; Mr. Aston, 6; Mr. Bates, 4; Dr. Cockayne, 6; Dr. Cotton, 6; Professor Easterfield, 4; Mr. Evans, 7; Dr. Frengley, 5; Mr. Furkert, 4; Mr. Ferguson, 4; Professor Hunter, 6; Mr. Holmes, 6; Mr. Lewis, 6; Dr. Maclaurin, 6; Mr. Montgomery, 4; Mr. Morgan, 7; Mr. Morton, 1; Mr. Parry, 2; Dr. Reakes, 4; Dr. Thomson, 6; Mr. Turner, 5; Mr. H. Hill, 1.

The Honorary Secretary of the New Zealand Institute was elected Honorary Secretary of this Committee. A sub-committee, consisting of Mr. George Hogben and Dr. Thomson, was set up to prepare a synopsis of the various schemes at present adopted by other countries for advancing science and industry. This was drawn up as a report by the sub-committee, submitted to the Hon. the Minister of Internal Affairs on the 2nd October, 1917, and at once published as a parliamentary paper, H.-47, 1917, *Organization of Scientific and Industrial Research,* and laid before Parliament, then sitting.

The Committee resolved that it was necessary that a research scheme should be prepared. A sub-committee was set up to draw up a list of suitable bodies and persons to circularize throughout the Dominion asking for any suggestions which they had to offer. The replies which were received were summarized by the Chairman.

The Committee took the scheme of the Wellington Philosophical Society (see Parliamentary Paper H.-47, 1917) as a basis for formulating a new scheme, and duly considering (*a*) the replies which had been received in answer to the Committee's circular, (*b*) the opinion of certain prominent scientific research workers who happened to be in Wellington at the Board of Studies meeting of the New Zealand University. Certain recommendations were drawn up advising the setting-up of a Board of Science and Industry, and prescribing the method of election or of appointment, and also the functions of the members of this proposed Board. The President of the New Zealand Institute having given his permission for this Committee to send their report in to the Government without consulting the Board of Governors as a whole (who nevertheless were kept informed by circular of the progress of the scheme), the report was sent in to the Chairman of the National Efficiency Board on the 9th November, 1917.

At the request of the Hon. the Minister of Internal Affairs, the Committee waited upon him on the 12th December, 1917, to hear his views and to give any advice desired as to the advancement of science and industry. The Minister promised to support the scheme drawn up by the Committee.

Mr. Ferguson informed the Hon. the Minister that the recommendations of the Committee would receive consideration at the meeting of the National Efficiency Board to be held on the 8th January, 1918, and were then to be sent on to the Government. (Your Committee is informed that this has now been done.)

At an early stage of the Committee's deliberations a motion was carried urging the Government to place on the supplementary estimates £2,000 for the purpose of promoting scientific research. This motion was forwarded through the National Efficiency Board to the Government.

The Prime Minister has informed the Board that the following sums have been placed on the estimates under the Department of Internal Affairs:—

	£
(1.) Dominion Laboratory—Scientific research	500
(2.) Miscellaneous Services—Grant to the New Zealand Institute for research work	500
(3.) Dominion Museum—Scientific and industrial research ..	250
	£1,250

As requested, the Standing Committee has extended the powers of the Scientific and Industrial Research Committee so that it may undertake the preliminary work of collecting data concerning New Zealand's industries and research workers, and facilities for carrying out the work. The Hon. the Minister of Internal Affairs having informed the Committee that he was prepared to take steps at an early date to inaugurate a Dominion scheme of scientific and industrial research by making a preliminary census of past research, actual problems of industry awaiting solution, and of available laboratories and research workers, and that there was a vote of £250 on the Museum estimates available for the purpose, the Committee advises that the Director of the Dominion Museum should undertake such census, and that a Committee of the New Zealand Institute should co-operate with him.

Annual Reports and Balance-sheets of the following incorporated societies have been received and are now laid on the table. No reports have been received from the Wanganui or the Nelson Societies.

Auckland Institute, to 22nd February, 1917.
Philosophical Institute of Canterbury, to 31st October, 1917.
Otago Institute, to 30th November, 1917.
Hawke's Bay Philosophical Institute, to 1st December, 1917.
Manawatu Philosophical Society, to 30th November, 1917.
Wellington Philosophical Society, to 30th September, 1917.

Auckland Institute Jubilee.—An illustrated pamphlet entitled *The First Fifty Years of the Auckland Institute and Museum, and its Future Aims, a Jubilee Sketch*, was published by the Auckland Institute in September, 1917. A copy is now laid on the table.

Public Meeting of the New Zealand Institute.—The desirability of holding a public meeting of the New Zealand Institute to arouse some public interest in scientific affairs, more especially in relation to industry, was discussed by the Committee, and Dr. Hector, Dr. Allan Thomson, Mr. Ewen, and the Hon. Secretary were appointed a sub-committee to make arrangements to hold it on the 30th January, 1917, the night of the last annual meeting, and the Town Hall was engaged for the purpose. It was not found possible, however, to obtain the necessary support at the time, and the matter was allowed to drop.

Honorary Treasurer's Reports.—The financial statements of the Honorary Treasurer, Mr. C. A. Ewen, comprising (*a*) Receipts and expenditure, (*b*) assets and liabilities, (*c*) the Carter Bequest, the Hutton Memorial Fund, and the Hector Memorial Fund, all of which were duly audited and certified by the Auditor-General, were adopted on the motion of Mr. Ewen, seconded by Mr. Birks.

The Public Trustee's reports on his administration of the Carter Bequest, the Hutton and the Hector Funds for the year ending 31st December, 1917, were adopted on the motion of Mr. Hill, seconded by Mr. Ewen.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR ENDING 31ST DECEMBER, 1917.

Receipts.	£	s.	d.	*Expenditure.*	£	s.	d.
Balance at 31st December, 1916	561	11	10	Hire Concert Chamber, Town Hall, for 30th January ..	2	2	0
Post Office Savings-bank interest to 31st December, 1917	15	6	1	McKay, custodian, preparing room and packing ..	3	0	0
Government grant (30th June)	500	0	0	Miss Bates, typing ..	4	10	0
Publications sold	47	19	5	Government Printer, Vol. 48, authors' copies and printing	599	17	0
City Corporation, refund rent hall not used	2	2	0	Governors' travelling-expenses	35	10	6
Wanganui Philosophical Society levy for year ending 31st December, 1916 ..	6	17	6	Grant for research to Philosophical Institute of Canterbury	110	0	0
Hawke's Bay Philosophical Society levy for year 1916	6	0	6	Grant for research to Wellington Philosophical Society	75	0	0
Nelson Institute levy for 1916	3	10	0	Grant for research to Hawke's Bay Philosophical Institute	20	0	0
Grant for research refunded by Mr. D. Petrie ..	20	0	0	Grant for research to D. Petrie	20	0	0
Grant from Treasury (1st February)	120	0	0	Fire-insurance premium, £1,500 on library	5	0	0
Grant from Treasury (28th March)	20	0	0	Hon. Editor, petty expenses	4	0	0
				Hon. Secretary, petty expenses	5	0	0
				Bank charge	0	10	0
				Balance in— P.O. Savings-bank .. £333 14s. 7d.; Bank of N.Z. £85 3s. 3d.	418	17	10
	£1,303	7	4		£1,303	7	4

STATEMENT OF LIABILITIES AND ASSETS AT 31ST DECEMBER, 1917.

	Liabilities. £ s. d.	Assets. £ s. d.
By Balance in Bank of New Zealand	..	85 3 3
Balance in Post Office Savings-bank	..	333 14 7
Hector Memorial Fund and per contra	1,106 13 9	1,106 13 9
Hutton Memorial Fund and per contra	787 11 5	787 11 5
Carter Bequest and per contra	4,138 5 11	4,138 5 11
Institute levies for year 1917 (per list)	..	124 7 6
Authors' copies and books sold	..	7 6 1
To Special grants for research purposes	45 0 0	..
Government Printer's account, authors' copies, &c.	88 13 0	..
Cost 1917 volume, No. 49	577 0 0	..
New Zealand Express Company	3 13 6	..
By Balance	..	163 15 1
	£6,746 17 7	£6,746 17 7
To Balance	£163 15 1	

Against this debit balance the Institute has a large stock of *Transactions* for sale, and possesses a very valuable library.

HECTOR MEMORIAL FUND.—STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR ENDING 31ST DECEMBER, 1917.

	£ s. d.	Dr. £ s. d.	Cr. £ s. d.
By Balance brought forward		..	1,093 18 0
Public Trust Office—			
Interest, 31st December, 1916, to 31st December, 1917	48 1 4		
Bonus for year ending 31st December, 1917	4 15 11	..	52 17 3
To New Zealand Institute—			
Hector Prize, awarded Professor Sir E. Rutherford		40 0 0	
Postages		0 1 6	..
Balance in hands of Public Trustee		1,106 13 9	..
		£1,146 15 3	£1,146 15 3
By Balance		..	£1,106 13 9

HUTTON MEMORIAL FUND.—STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR ENDING 31ST DECEMBER, 1917.

	£ s. d.	Dr. £ s. d.	Cr. £ s. d.
By Balance brought forward		..	750 10 5
Public Trust Office—			
Interest, 31st December, 1916, to 31st December, 1917	33 14 8		
Bonus for year ending 31st March, 1917	3 6 4	..	37 1 0
To Balance in hands of Public Trustee		787 11 5	..
		£787 11 5	£787 11 5
By Balance		..	£787 11 5

CARTER BEQUEST.—STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR ENDING 31ST DECEMBER, 1917.

	Dr. £ s. d.	Cr. £ s. d.
By Balance brought forward	..	3,944 3 5
Public Trust Office—		
Interest from 31st December, 1916, to 31st December, 1917	..	177 5 10
Bonus interest from 31st December, 1916, to 31st December, 1917	..	17 1 11
To Public Trustee—		
Commission	0 5 3	
Balance in hands of Public Trustee	4,138 5 11	..
	£4,138 11 2	£4,138 11 2
By Balance	..	£4,138 5 11

Financial Position.—After a general discussion on the financial position of the Institute it was resolved, on the motion of Mr. Ewen, seconded by Dr. Cockayne, That for every copy of Volume 50 of the *Transactions* received by the incorporated societies a contribution of 2s. 6d. towards the cost of printing shall be made during the current year by such society. On the motion of Professor Thomas, seconded by Mr. Hill, it was resolved, That strong representations be made to the Government by the New Zealand Institute with the view of obtaining an increased grant of £750 for this year for the publication of the *Transactions* and other scientific work.

Hutton Grant for Research.—Mr. G. M. Thomson, Chairman of the Portobello Fish-hatchery, read a further report of the work carried out during 1917, which had been assisted by a grant from the Hutton Fund in January, 1916.

Hector Award for 1918.—The recommendations of the Committee of Award—Professor Chilton, Dr. Cockayne (convener), Professor Easterfield, and Professor P. Marshall—was received in a sealed envelope by the President, and the recommendation awarding the medal and prize to Mr. T. F. Cheeseman, of Auckland, was adopted on the motion of Professor Thomas, seconded by Mr. G. M. Thomson.

REPORT OF THE HECTOR MEMORIAL AWARD COMMITTEE.

The members of the Hector Memorial Award Committee for 1918—Professor C. Chilton, Dr. L. Cockayne, Professor T. H. Easterfield, and Dr. P. Marshall—having carefully considered the claims of all botanists who, in their opinion, might be entitled to receive the Hector Memorial Medal and Prize, have unanimously decided to recommend Mr. T. F. Cheeseman, F.L.S., F.Z.S., as the recipient of the award.

This they do on the grounds not only of the great excellence of Mr. Cheeseman's published researches on New Zealand systematic botany, phytogeography, and floral biology, which have been carried on without a break since the early "seventies" of the last century, but also because of the supreme influence of his work, especially of his admirable *Manual of the New Zealand Flora*, upon botanical investigation throughout the Dominion.

LEONARD COCKAYNE,
Convener of the Committee.

Publication Committee's Report.—On the motion of Dr. Cockayne, the Publication Committee's report was adopted. On the motion of Dr. Hilgendorf, seconded by Professor Segar, it was resolved, That the question of inserting the date of receipt of papers by the Honorary Editors be left to the Publication Committee.

REPORT OF THE PUBLICATION COMMITTEE.

Sixty papers were offered for publication, and of these fifty were accepted by the Committee for publication in Volume 49 of the *Transactions*. It was decided to deposit the manuscript of another paper in the library of the New Zealand Institute and to publish the title, so that this might be indexed and give information to other workers as to the availability of the work. It is proposed to treat similarly other papers so deposited in the future. The remainder of the papers were withdrawn, held over, or declined.

Volume 49 of the *Transactions and Proceedings of the New Zealand Institute* was issued on the 20th December, 1917. It contained xvi + 618 pages (of which 88 are devoted to the Proceedings), 37 plates, and many text-figures.

The late publication of the volume must be accepted as a direct consequence of the war, which has depleted the staff of the Government Printing Office and supplied it with a large amount of extra work of an urgent nature. It must be remembered that the publication of scientific matter is undertaken by the Government Printing Office only in the slack season. When the pressure of urgent work for Government Departments increases, the time available for work on the Institute's publications is reduced. The Committee is of the opinion that the Institute is deeply indebted to the Government Printing Office for maintaining the high standard of typographical work in the *Transactions* in these trying times, and, while regretting the lateness of the publication of Volume 49, realizes that the lateness resulted from uncontrollable circumstances.

An innovation that has given much satisfaction is the issuing of authors' copies of articles in Volume 49 in advance of publication of the volume. This was authorized by a resolution of the Board of Governors, and has resulted in giving early publication to those papers in particular which appear in the early pages of the *Transactions*. Each paper bears the date of issue, and, in accordance with the resolution of the Board of Governors, the date of receipt of the manuscript by the Editors. The latter, however, is at present meaningless, since the manuscripts are generally retained by the Secretaries of the incorporated societies until the last week of December. Moreover, the only apparent reason for recording the date of receipt is to insure page priority in the volume, and no resolution to this effect has been passed. If this is the intention of the Board of Governors, it necessitates a revision of the method of transmission of manuscripts from the authors to the Editors, and also involves a departure from the present method of arrangement of papers in the volume according to subjects and authors. If this is not the intention, the insertion of the date of receipt of the manuscript seems useless.

The Committee recommends that the Secretaries of the incorporated societies be requested to send the manuscripts of papers to the Editors as soon as possible after they have been read. If this is done, much earlier publication of the authors' copies than has been usual may be expected. Early receipt of the manuscripts will also allow these to be returned to the authors when extensive alterations are required, and, in some cases, will obviate the necessity of holding over such papers for a year.

Bulletin No. 1, Part V, on the *New Zealand Coleoptera*, by Major T. Broun, was published on the 26th June, 1917, and contains 128 pages of text. Publication of the other three bulletins mentioned in the 1917 report is still delayed owing to shortage of funds.

The Committee wishes to draw attention to the fact that the majority of manuscripts as received are not well prepared for publication either as regards text or illustrations. The "Memorandum for Authors of Papers" published annually in the *Transactions* is evidently seldom consulted.

For the Committee.

L. COCKAYNE, }
C. A. COTTON, } Hon. Editors.

The Hon. the Minister of Internal Affairs, Mr. G. W. Russell, was at this stage welcomed by the President.

The President thanked the Hon. the Minister of Internal Affairs for addressing the meeting, and for his promise of further assistance to the Institute.

Report of the Library Committee.—The Hon. Librarian's report was adopted on the motion of Dr. Thomson, seconded by Mr. Hill.

REPORT OF LIBRARY COMMITTEE.

The incoming exchanges have been received, registered, and placed upon the shelves. As the Institute has not been able to devote any funds to bookbinding

since 1904, the task of keeping the library in an efficient state yearly becomes more difficult. In the opinion of the Committee the time has come when the Institute should make a strong appeal to the Government for additional funds specifically allotted to the binding of the Institute's library, which has already been offered, under conditions not yet fixed, to the Board of Science and Art.

The compilation of the index cards for 1915 for the *International Catalogue of Scientific Literature* was referred to the Library Committee, and the cards for many of the subjects have been prepared, but have been withheld until the Board of Governors reconsidered the whole subject.

The only New Zealand journals recognized by the *International Catalogue* are the *Transactions, Proceedings,* and *Bulletins* of the New Zealand Institute, the *Journal of Agriculture,* the *Polynesian Journal,* and the *Journal of the British Medical Association (N.Z. Branch).* The following important serials are omitted from the list: the *Bulletins* and *Palaeontological Bulletins* of the New Zealand Geological Survey, the *Bulletins of the Dominion Museum,* and the *Appendices to the Journals of the House of Representatives,* which last contain the annual reports of Departments and occasional scientific papers of importance.

It is the duty of the New Zealand Institute, acting as the Regional Bureau for New Zealand, to make representations to the International Council as to what New Zealand journals should be indexed, and your Committee felt that it was inadvisable to send forward the cards already prepared for 1915 until the Board of Governors had considered the whole matter. We are further of opinion that the International Council should be asked to forward their annual report each year, so that affairs of the *International Catalogue* may come up automatically before the Board of Governors.

J. Allan Thomson,
Hon. Librarian.

Binding of Books.—On the motion of Mr. Hill, seconded by Mr. G. M. Thomson, it was resolved, That application be made to the Minister of Internal Affairs for a grant, as soon as circumstances permit, sufficient to provide for binding the large number of unbound publications now in the library of the Institute.

International Catalogue of Scientific Literature.—On the motion of Dr. Thomson, seconded by Mr. Parr, it was resolved, That the following be added to the list of serials to be indexed for the *International Catalogue of Scientific Literature,* and sent to the International Council:—

(1.) *Bulletins* and *Palaeontological Bulletins* of the New Zealand Geological Survey.
(2.) *Bulletins* of the Dominion Museum.
(3.) *Bulletins* of the Board of Science and Art.
(4.) *The New Zealand Journal of Science and Technology.*
(5.) *Appendices to the Journals of the House of Representatives.*
(6.) *Public Health Reports.*

It was resolved, on the motion of Dr. Thomson, seconded by Professor Segar, That the International Council be informed that the New Zealand Institute considered it important that Government publications should be indexed in the *International Catalogue of Scientific Literature,* and that the Library Committee be instructed to draft a letter explaining the position.

On the motion of Dr. Thomson, seconded by Professor Thomas, it was resolved, That Professor Dendy be appointed to represent the New Zealand Institute on the International Council of the *International Catalogue of Scientific Literature.*

Bulletins.—The matter of publishing future bulletins was left in the hands of the Publication Committee to deal with at their discretion.

Library Catalogue.—Dr. Thomson explained the system of multiple card-indexing museum exhibits, and suggested that it might be made to apply to a library catalogue.

The Report of the Research Grant Committee was read, and, on the motion of Mr. Aston, seconded by Dr. Thomson, was adopted. On the motion of Dr. Hilgendorf, seconded by Professor Segar, it was resolved, That the grants already voted but not expended be renewed to the original applicants for the coming year.

On the motion of Dr. Hilgendorf, seconded by Mr. Hogben, it was resolved, That all applications for research grants be made through incorporated societies.

REPORT OF THE RESEARCH GRANT COMMITTEE.

(Professor Easterfield, Dr. Allan Thomson, and Mr. B. C. Aston.)

The grantees for 1916–17 (see *Trans. and Proc., N.Z. Inst.*, vol. 49, p. 580) have reported as follows:—

Mr. L. Symes (Canterbury Philosophical Institute) reports (15/12/17) that no portion of the grant has been expended, owing to the difficulty of obtaining the necessary assistance. Some preliminary work has been done, but little progress can be reported. The grantee asks that the grant be renewed for the coming year. A committee of the Canterbury Philosophical Institute, consisting of Messrs. Hilgendorf, Page, Wild, Martin, and the grantee, has been appointed to carry on the work during the coming season.

Mr. L. Birks (Canterbury Philosophical Institute) reports (28/1/18) that the grant has not been touched, but asks that the same sum be voted for this year.

Messrs. Speight and Wild (Canterbury Philosophical Institute) report (1/12/17) having visited various localities in the South Island and having expended out of the grant of £50 the sum of £21 10s. 9d. in travelling-expenses. The work done they regard as preliminary to the attack on the problem from the commercial standpoint.

Mr. H. Hill (Hawke's Bay Philosophical Institute) furnishes (20/11/17) a narrative of his journey across the Taupo Plains, with complete statements of expenditure, showing that the grant has been fully expended.

Professor Kirk (23/12/17) supplies an interim report, with a statement of £12 2s. expended out of £25 voted, and asks that the unexpended balance be allowed to stand over for another year.

Messrs. La Trobe and Adams report (24/1/18) that £64 1s. 6d. has been spent in the construction of apparatus, and make application for a further grant of £75.

Professor Jack (Otago Institute) has not been able to do anything towards the research for which £25 was voted but not paid, and asks (15/1/18) that the grant be renewed for 1918.

Mr. D. Petrie (Auckland Institute), being unable to take up the research for which £20 was granted, has surrendered his grant, and the money has been paid to the Institute.

Hamilton Memorial.—The report of the Hamilton Memorial Committee of the Wellington Philosophical Society, showing photographs of the stone selected and specifications and inscriptions in Maori and English, was read and received.

On the motion of Mr. Birks, it was resolved to thank the Hamilton Memorial Committee for their action.

On the motion of Mr. Hogben, seconded by Mr. Birks, it was resolved, That the Standing Committee be authorized to co-operate with the Wellington Philosophical Society in arranging the terms on which the balance of the Hamilton Memorial Fund should be handed over in trust to the New Zealand Institute.

REPORT OF THE HAMILTON MEMORIAL COMMITTEE OF THE WELLINGTON PHILOSOPHICAL SOCIETY.

The Committee has to report that in response to a circular asking for subscriptions for a memorial to the late Mr. Augustus Hamilton, the sum of £122 2s. 10d. was received.

After consultation with the family of the late Mr. Hamilton, the Committee decided to have a suitable monolith erected over the grave at Russell, Bay of Islands.

A number of designs were considered, and the one prepared by the Government Architect, Mr. J. Campbell, F.R.I.B.A., was adopted. Working drawings and specifications were prepared by Mr. Campbell, and steps were then taken to obtain a suitable

block of stone. Inquiries were made at a number of quarries, and finally a block of Kairuru marble was selected by the Committee and approved by Mr. H. Hamilton. The block stands on a concrete base faced by four pieces of the same kind of marble, covering an area of 4 ft. 6 in. by 3 ft. 7 in. A bronze tablet is mounted on the main block, and has the following inscription in raised letters:—

AUGUSTUS HAMILTON
1853–1913
DIRECTOR OF THE DOMINION MUSEUM
WELLINGTON
AN EMINENT STUDENT OF MAORI LORE
A LOVER OF NATURE
AN EARNEST SEEKER AFTER TRUTH

A bronze tablet is mounted in the marble base, and has the following inscription in raised letters:—

KO TENEI PAKEHA KO HAMUTANA HE HOA TUTURU NO TE IWI MAORI, A HE TANGATA MANAAKI HOKI I NGA RAWA O MUA O TE MAORI, ME NGA KAUWHAU O NEHE. KOIA I TAPAIA AI TONA INGOA KO TUPAI TE AHORANGI; TE WHATU O TE WHARE WANANGA, ME TE KAI TIAKI O TE KETE ARONUI.

This may be translated as—

"This European Hamilton was a firm friend of the Maori people, a person who treasured their old-time works and ancient lore. Hence he was named Tupai te Ahorangi—the Core of the House of Learning, the Preserver of Occult Knowledge."

The thanks of the Committee are tendered to Mr. R. W. Holmes, Engineer-in-Chief, and Mr. John Wood, District Engineer, Public Works Department; to Mr. Elsdon Best; to Mr. J. Campbell, Government Architect; to Mr. G. Allport, Secretary for Marine; and to Captain Bollons, of the Government steamer "Hinemoa," for valuable services rendered.

Through the actions of these gentlemen in saving expenses the Committee is enabled to hand over with this report an unexpended balance of £38 2s. 3d. The Committee recommends that this sum be invested by the New Zealand Institute, and that each year one half of the interest be added to the principal, and that the other half of the interest be devoted to a prize to be called the Hamilton Prize. The prize should be awarded from time to time by the New Zealand Institute to the author whose first scientific writings which shall be deemed worthy of the honour of the prize shall have appeared in the *Transactions of the New Zealand Institute* or other similar publication in New Zealand. The intention of the Committee is that the prize be restricted for competition among beginners in scientific research. The Committee has to report that this proposal is approved by the Hamilton family.

Specifications, working drawings, and photographs of the monument are forwarded herewith.

C. MONRO HECTOR, Chairman.
T. H. EASTERFIELD.
C. E. ADAMS, Secretary.

Wellington, 24th October, 1917.

New Zealand Mean Time.—A letter (20/12/17) from the Wellington Philosophical Society enclosing a printed report of a Committee of the Council of the Wellington Philosophical Society entitled "New Zealand Standard Time" was received. On the motion of Mr. Birks, seconded by Dr. J. Allan Thomson, it was resolved by nine votes to five, That the New Zealand Institute endorse the resolution of the Wellington Philosophical Society regarding the alteration of New Zealand mean time.

Bird-protection.—A letter from the Royal Zoological and Acclimatisation Society of Victoria, Melbourne (15/10/17), was read and received. On the motion of Professor Kirk, seconded by Professor Thomas, it was resolved, That the Institute is in sympathy with all movements for the protection of

harmless birds, and is prepared to co-operate with the Forest and Bird Protection Society in this direction.

Kapiti Island Sanctuary.—On the motion of Dr. Thomson, it was resolved, That Professor Kirk and Mr. Eliott, be a committee to visit and report on Kapiti Island at the next meeting, and that their expenses be reimbursed by the Institute.

Other Correspondence.—Letters (*d*), (*e*), (*f*), (*g*), (*h*), (*i*), from the Internal Affairs Department, were read and received :—

(*d*.) Protection of fur seals. (2/3/17.)
(*e*.) Resolutions of the last meeting. (14/6/17.)
(*f*.) Catalogue of New Zealand fishes. (14/3/17.)
(*g*.) Housing library. (1/3/17.)
(*h*.) Increase in grant to New Zealand Institute. (2/2/17.)
(*i*.) Museum library. (1/2/17.)

Dominion Museum.—It was resolved, on the motion of Professor Kirk, to again draw the attention of the Government to the following resolution passed at last year's annual meeting: "That the attention of the Government be again called to the fact that the Dominion Museum collection, including many valuable records and objects that could by no possibility be replaced, are still housed in an old and highly combustible wooden building."

Sounds National Park.—On the motion of Mr. Birks, seconded by Mr. Eliott, it was resolved, That the New Zealand Institute respectfully urges that the protection of seals in the Sounds National Park and Cascade Point be not delayed until the end of the war, but be dealt with by a clause in the Legislative Amendment Bill.

Louvain University.—A letter was received from M. P. Delannoy, Librarian of the University of Louvain, intimating that until a public depot for the reception of gift books for the University library restoration has been arranged for it will be better to keep any gifts from New Zealand in this country.

Science Worthies.—Letters were read from Mr. Henry Suter (8/2/17) and Major Thomas Broun (12/1/8) thanking the Institute for the congratulatory letters (see p. 542, vol. 49). Dr. Thomson announced that he had visited the late Mr. Alexander McKay, who received the letter of the Institute during his last illness, and it was evident that the resolution of the Board had given him sincere pleasure.

Société d'Études Océaniennes.—The Honorary Librarian mentioned that he had received publications of this society, and on his motion, seconded by Mr. G. M. Thomson, it was resolved, That the congratulations of the New Zealand Institute be accorded to the Société d'Études Océaniennes on its foundation, and on the publication of its bulletin.

Deaths of Honorary Members.—The Honorary Librarian read a postcard announcing the death of Dr. S. Berggren, at Lund, which, in addition to the three mentioned in the President's address—viz., Rev. O. Pickard-Cambridge, Richard Lydekker, and George Massee—makes four vacancies in the roll of honorary members to be filled.

Amendment of Regulation.—On the motion of Professor Kirk, seconded by Dr. Cockayne, it was resolved, That regulation 5 (*a*) (1) be amended to read as follows :—

" (*a*.) The publications of the Institute shall consist of—(1) Such current abstract of the proceedings of the societies for the time being incorporated with the Institute as the Board of Governors deems desirable."

New Zealand Journal of Science and Technology.—Dr. Thomson laid on the table the first number of this *Journal*. He promised to communicate with the Secretaries of societies regarding the printing in the *Journal* of matter suitable suitable for the *Journal* and not for the *Transactions* of the Institute.

Proposed Department of Scientific Affairs.—Mr. G. M. Thomson withdrew his motion regarding the establishment of a Department of Scientific Affairs (see *Trans. N.Z. Inst.*, vol. 49, p. 542).

Election of Officers.—The following officers for the ensuing year were elected: President, Dr. L. Cockayne, F.R.S.; Hon. Editors, Drs. L. Cockayne and C. A. Cotton; Hon. Treasurer, Mr. C. A. Ewen; Hon. Secretary, Mr. B. C. Aston, F.I.C.; Hon. Librarian, Dr. J. Allan Thomson.

Publication Committee.—Professor Kirk, Drs. Cockayne, Cotton, and Thomson, Messrs. Aston and Hogben.

Library Committee.—Drs. Cockayne and Cotton and the Hon. Librarian.

Research Grant Committee.—Professor Easterfield, Messrs. Hogben and Aston.

Hector Award Committee.—Professor Easterfield (convener), Drs. Chilton, Cockayne, and Marshall.

Date and Place of the next Annual Meeting.—It was resolved, That the next annual meeting be held at Wellington on the 17th January, 1919.

Travelling-expenses.—It was resolved, on the motion of Dr. Thomson, That the travelling-expenses of members of the Board to this meeting be paid by the Institute.

Votes of Thanks to the retiring President for the able manner in which he had carried out the duties of his office for the past two years, and to the other officers, were unanimously carried. The Honorary Librarian desired to specially acknowledge the assistance he had received from Mr. McDonald in the library during the year.

The meeting adjourned until the following day.

The meeting resumed its sitting on Wednesday, the 30th January, 1918, at 9 a.m.

Present: Professors Benham, President (in the chair), Thomas, Segar, Kirk, Drs. Cockayne, Hilgendorf, Thomson, Messrs. Aston, Birks, Ewen, Eliott, Hill, Hogben, Parr, and G. M. Thomson.

President's Address.—The following motions arising out of the suggestions contained in the President's address were brought forward by Dr. Hilgendorf:—

Compliance of Incorporated Societies with Regulations.—On the motion of Dr. Hilgendorf, seconded by Professor Segar, it was resolved, That in

accordance with the President's suggestion the Treasurer be asked to examine the balance-sheets of the incorporated societies, and to report annually as to the compliance of incorporated societies with Regulation No. 3.

Publication of the Minutes of the Annual Meeting.—On the motion of Dr. Hilgendorf, seconded by Mr. G. M. Thomson, it was resolved, That it be suggested to the Publication Committee that the report of the annual meeting of the Institute be printed and circulated to the affiliated Institutes as soon as possible after the meeting, as well as being incorporated in the *Transactions* in due course.

Establishment of an Endowment Fund.—Dr. Thomson, who previously at the meeting had given notice of his intention, now moved that an Endowment Fund be set up, the interest of which may be spent in any year for any purposes of the Institute, but the principal may not be spent. The motion was seconded by Professor Kirk, and carried.

Reform of the Institute.—The replies from the incorporated societies which had been received in answer to Dr. Thomson's proposals were laid on the table. On the motion of Dr. Cockayne, seconded by Mr. Hill, it was resolved, That a Committee be set up to report at next meeting on the matter of Fellowship of the Institute; and on the motion of Mr. Parr, seconded by Mr. Eliott, it was resolved, That Mr. Hogben, Dr. Thomson, and Dr. Cockayne (convener) be appointed a Committee to draw up a scheme and refer it to the incorporated societies. On the motion of Mr. Birks, seconded by Mr. Hill, it was resolved, That this Board express its appreciation to Dr. J. Allan Thomson of his action in bringing forward the proposals dealing with the constitution of the Institute.

Public Meeting of the Institute.—On the motion of Dr. J. Allan Thomson, seconded by Mr. G. M. Thomson, it was resolved, That the Institute accept the invitation of the Philosophical Institute of Canterbury to hold a week of meetings in Christchurch in the autumn of 1919.

Co-ordination of Science and Industry.—Further reports were received from the incorporated societies, and were laid on the table.

Board of Science and Industry.—On the motion of Professor Kirk, seconded by Mr. Birks, it was resolved, That this meeting of the Board of Governors of the New Zealand Institute considers it an essential part of the scheme for scientific and industrial research that the Board should be a trust to administer public and other funds given for the purpose for which it is constituted, and that for the first five years its finance should not be subjected to any amendment by Parliament, although duly audited; and that Mr. Hogben and Dr. Thomson be a committee to transmit this resolution to the Government, after consultation with the National Efficiency Board.

Vote of Thanks to the New Zealand Institute's Scientific and Industrial Research Committee.—It was resolved, on the motion of Professor Thomas, seconded by Dr. Hilgendorf, That this meeting expresses its appreciation of the work of the New Zealand Institute's Scientific and Industrial Research Committee, under the chairmanship of Mr. George Hogben, and is indebted to it for its successful efforts to embody the opinion of the Committees in the respective centres of New Zealand.

Census of Industries.—On the motion of Mr. Hogben, seconded by Mr. G. M. Thomson, it was resolved, That a Committee be set up to co-operate

with the Director of the Dominion Museum in making a preliminary census of matters connected with scientific and industrial research. It was resolved that the following be the Committee, with the power to add to their number: Dr. Cockayne, Messrs. Hogben, Aston, Kirk, and Parry. It was resolved to leave the arrangements for carrying on propaganda in connection with science and industry to the same Committee.

Confirmation of Minutes.—It was left to the Publication Committee, on Friday, the 1st February, 1918, to confirm the minutes of the annual meeting and to decide whether it was desirable to publish Appendices A, B, and C to the annual report.

ADDRESS OF THE PRESIDENT.

The following is the presidential address delivered at the annual meeting of the Board of Governors of the New Zealand Institute, at Wellington, on the 29th January, 1918, by Professor W. B. Benham, F.R.S.:—

Gentlemen,—My thanks are due to you for doing me the honour of re-electing me to the Presidency of the Institute for a second year—a year that has been marked by the great activity of the Standing Committee in relation to the important work of endeavouring to draw up a scheme for the correlation of science and industry, to which I will refer later.

Too little attention, I think, has been paid in past times to those of our own men of science who have passed away. Recently my attention was called to the fact that no memoir, no obituary notice even, is to be found in our *Transactions* of some who have done good service, especially to natural science, in New Zealand. Thus the work of Colenso and of Parker, to mention but two, is not recorded in our volumes. I think this should be rectified in the future, and that one of our officers, or some one else, should, while it is yet time, get together the salient facts of the life-history of those who are at present working, so that their contributions to the progress of science in New Zealand may receive due recognition.

It would be a very laborious task to write a history of the gradual building-up of science in New Zealand at the present time, and I am glad to see that Mr. G. M. Thomson is at present engaged in writing a series of articles on our naturalists in the *Otago Witness.* These will form a very valuable contribution to our history. It is, I think, a wise thing to recall to our minds from time to time the gradual steps by which each of our sciences has been built up, and the names of the men who have thus helped us: we are too much interested in the present-day problems to consider their history, and yet much of our present work is merely adding a brick or two to the edifice whose foundations have been laid in the past. Let us not think too greatly of the importance of that single brick, but rather think humbly of our own small contributions.

I had intended to refer to some of the distinguished men of science who have passed away during the year, but I find my address already too long. Two of our honorary members are included in this list, while Lydekker, who died in 1916, should have been referred to in my last address

The Rev. *Octavius Pickard-Cambridge,* F.R.S., who was for fifty years vicar of Bloxworth, in Dorset, died in March, 1917, at the age of eighty-eight, and was one of the world's authorities on trap-door spiders, on which he contributed two papers to our *Transactions* describing some of our native species. Few naturalists of equal calibre are less revealed by their published work. He was a systematist, a describer and identifier of species, and though in this line of work no particularly brilliant discoveries are associated with his name, it is work requiring rather special gifts of careful observation, an absolutely necessary work on which biologists can build.

George Massee, F.L.S., was aged sixty-seven when he died, in 1917. For twenty years he was head of the Crypytogamic Department at Kew, where he specialized on fungi. He published several systematic works on the group, and later turned his attention to those which produce disease in plants, on which he published several descriptive works, useful alike to the botanist and the agriculturist. He contributed two papers to our *Transactions* on the fungus flora of New Zealand. He combined the skill of the artist with the accuracy of observation of the scientist, many of his drawings which illustrate his work's being of great beauty.

It seems that the death of these two honorary members has been overlooked, as the affiliated societies were not notified of any vacancies in the list, of which there are now three.*

It is unfortunate that the New Zealand Institute as a scientific body has no funds from which a contribution can be made to the memorial to the late Sir William Ramsay, F.R.S., Professor of Chemistry, and that we have to leave this and similar matters to the affiliated societies. It would certainly bring kudos to the Institute if its name figured amongst the subscribers to such a memorial as this.

There will be presented to you a summary of the steps taken by the Standing Committee, with which was associated a number of gentlemen interested in industrial matters, to elaborate a scheme for the co-ordination of scientific and industrial research; so that I need do little more than allude to it. There has been issued by the Government a report, signed by Mr. Hogben and Dr. Thomson, of the steps that have been taken in other parts of the Empire, and of certain schemes proposed by various bodies in New Zealand, with this object in view. Moreover, the final report of the above Committee has, I believe, been circulated.

I trust that this important matter will not be allowed to rest, but that steps will be taken to persuade the Government of the very serious need for encouraging in every way, and especially by generous financial support, the prosecution of scientific research—not merely of research as applied to industry, but also, and primarily, of research in pure science, which, as we all know, is the foundation of the former. It has taken the scientific men of Britain over forty years to convince the British Government of the value of scientific research, for as long ago as 1870 a Royal Commission recommended the establishment of a State Council of Science presided over by a Minister of Science.

As Professor Pope pointed out in an address delivered in October last, "If suitable provision had been made by the State for the pursuit of scientific research even twenty years ago, we should have been spared the horrors of the present conflict." It is only now, as the result of the urgent appeals of scientific men in Britain since the commencement of the war, that the British Government have established a Department of Scientific and Industrial Research, with an endowment of £1,000,000. Since the war began the public have awakened to the fact that all our present needs and comforts in ordinary life are the outcome of discoveries made by scientific men in their laboratories, and several books (such as Gregory's *Discovery: The Spirit and Service of Science*, and, under Seward's editorship, the series of articles by Cambridge men of science issued under the title *Science and the Nation*) have been published putting the facts plainly before us, and impressing upon the public that much of our backwardness in the British Empire is due to inadequate recognition, financial and social, of scientific research. We may hope that the British Government, at least, may thus become acquainted with the value of scientific discovery.

Here in New Zealand there is need for a constant reminder of these facts: the Councils of our University colleges must be urged again and again to make proper provision for carrying on researches in pure science, for no one can foresee what use may ultimately be made of some apparently trivial discovery in the laboratory; and the more intimate association of industrialists with scientific men is needed so that they may be kept in touch with the progress of science. It is not enough, however, to draw up a scheme for the purpose of bringing this about: provision must be made for obtaining men to do research. At the recent meeting of the University Senate a letter was received from one of the Professors of Chemistry pointing out that it is better to provide adequate trained assistance to a professor, who would thus be relieved of some of the routine work of his chair and might then be able to devote time to research, than to award scholarships to graduates. This is certainly true; and it is also necessary that greater encouragement should be given to our graduates to continue their studies in the University colleges, and to learn how to carry out research work. At present the only inducement held out to them is a National Research Scholarship, one of which is available each year at each of the four colleges. But the Professorial Boards have repeatedly pointed out to the Education Department that the sum of £100 annually for two years is not sufficient to attract students unless they have independent means, for after spending four or five years in taking their Honours degree they naturally wish to begin earning a livelihood, and are therefore more readily attracted to the teaching profession, where a capable man or woman may obtain a salary of £150 to £180 as a teacher of science in a high school. These Research Scholarships should be made more valuable and increased in number; and other inducements should be held out to our graduates, so that we may encourage those of our students who are capable of research to con-

* The death of Dr. Berggren was also announced at the annual meeting.

tinue with us. If the colleges had the funds wherewith to provide adequate payment to trained assistants and demonstrators so that they would remain more than a year or two at the college and be trained in research as well as in teaching, this would relieve the professors, and the college would be able to provide men and women capable of aiding our industrialists in solving their problems.

But without a supply of such men any scheme for scientific and industrial research loses much of its point and value. And in the present scheme, although reference is made to increasing the number and value of these Research Scholarships, it does not seem to me that the Committee have sufficiently considered the mode of supply of requisite students. This is precisely what is being felt in Britain, where unfortunately many of the younger men of science have suffered death in this war instead of having been retained for the vastly important work of the future peace.

Moreover, one reason why so many capable research students enter the teaching profession in Britain, as here, is that manufacturers have not seen fit, in most cases, to offer to trained researchers sufficient remuneration.

Unless the professors are relieved of much of their routine work, and until it is recognized that the first duty of a professor is the promotion of research rather than teaching, the award of scholarships will be in vain, and the introduction of graduates into industry will not lead to the developments necessary to carry out the ideal set out in the scheme for improving our industrial position in the world.

In the covering letter signed by Mr. Hogben, Chairman of Committee, to the Chairman of the National Efficiency Board I notice an important proposal—viz., that some system of propaganda should be started. This is necessary, as the industrialists are no doubt in ignorance of what has been taking place, what steps are proposed, and, indeed, of the importance of the whole scheme. Almost too much stress seems to be laid in this report on research, and too little on the utilization of the scientific knowledge which has been accumulated by investigators in other countries. Hence the great importance of the propaganda hinted at by Mr. Hogben. What is so pre-eminently needed here, as in Britain, is a campaign to disseminate the scientific spirit throughout the community; for unless we educate the entire people as to the value of the scientific method the object of this scheme will, I fear, be but temporarily and partially attained, and the movement so carefully elaborated by the Committee will soon collapse owing to the absence of any firm foundation in education.

I do not know whether I ought to criticize the report of the Committee, but it seems to me that the method of election of the four members the Board is very elaborate, and the constitution of the local Advisory Boards too large, and there is no indication of where researches are to be conducted.

That it does not require a great amount of organization to produce useful research in regard to industry is seen by what has been done in South Australia. The South Australian Government Department of Chemistry, under Dr. Hargreaves, has issued nine bulletins dealing with possible new industries, and with industrial research on such matters as—Bonedust, its adulteration with phosphate rock; alcohol as a source of power; foaming of boiler waters; grass-trees (*Xanthorrhoea*), their economic products; potash, its economic sources; wool-fat, its recovery and purification; cream of tartar, its manufacture; marine fibre, attempts to utilize.

Another matter that will come before us is a report as to the proposed reform of the New Zealand Institute, which originated with Dr. J. Allan Thomson and the Wellington Philosophical Society. The proposals have been criticized by the affiliated societies chiefly in regard to the proposed new kind of membership and the change in name of the existing members to that of "associates." All the societies seem in favour of the establishment of Fellows, but if this be carried out we must guard the privilege of fellowship very jealously and put a definite limit on the number of Fellows to be elected annually, for there are not very many workers in science who are doing or have done work of such a high-class character as to entitle them to this distinction, and the number will soon become exhausted, so that unless a limit is placed on the number of Fellows it will become almost a matter of course that any worker would be nominated and the title would soon cease to have any honour attached to it. But the proposals have another aim, that of increasing the funds of the Institute, and I do not see that in this respect much is to be hoped for from the reform proposed.

In my address at the last annual meeting of the Governors I referred to the Cawthron Institute. The report of the Commission appointed by the Trustees to draw up a scheme for the proper working of this Institute of research has now been presented to the Trustees, who are acting on the lines therein recommended. As the matter is one of very great importance for the future development of scientific work, it may be desirable to put the gist of the report on record here. The Institute will be erected, when the war

is ended, close to the city of Nelson. The work will be scientific research into the problems of agriculture, particularly as affecting the growing of fruit, as this is the leading feature of the provincial district. It is hoped that agricultural problems of all kinds will in the future be studied—diseases of trees, improvement in culture, the chemistry and physics of the soil, the development of forest land, &c.; and in time the work may be extended in other directions. Hitherto, as we are aware, no institution in New Zealand has been wholly or even mainly given up to scientific research, but the Cawthron Institute will be equipped, financed, and organized for this purpose alone. The sum of money at the disposal of the Trustees is about £200,000, and the Trustees, who are for the most part business men, are determined that the annual expenses shall not exceed the income from the principal. Interest is accumulating, and from this it is proposed to erect the necessary buildings after the Director has been appointed and in consultation with him. The site has already been purchased and surveyed; a caretaker has been appointed and is now looking after the orchard on the property. The Institute will be governed, under the Trustees, by an Advisory Board acting with the Director. On the Advisory Board the following bodies will be represented: the Cawthron Trustees, the Board of Agriculture, the Nelson Institute, the Board of Studies of the New Zealand University, and the Governors of the New Zealand Institute. Whether any formal intimation* to this effect has been received by our Secretary I do not know, but according to the report of the Commission we ought to nominate our representatives at this meeting. As a Director it is hoped to obtain a first-class chemist from England who has had experience of agricultural problems, but is not likely that he will be appointed until the war is over. When fully staffed it is intended that plant-physiology and plant-pathology, economic zoology and geology will be represented—but that will be in the future; at the outset the Director will be assisted by a plant-pathologist and an orchardist, to whom adequate salaries will be paid.

Provision will be made for the award of scholarships as follows: (*a*) A Nelson Scholarship to allow boys and girls to equip themselves at a University college to become students of the Institute; (*b*) a Cawthron Scholarship to encourage brilliant scientific graduates to continue their work at the Institute; (*c*) a Cawthron Fellowship of sufficient value to retain the services of such scholars and other students; (*d*) an Industrial Fellowship which may be established by any body of industrialists who desires any special researches undertaken and who will pay the salary of this Fellow; (*e*) an annual Cawthron Lectureship, the first holder of which is Professor Easterfield, who has already given the lecture. Of these scholarships it was suggested that the first should be awarded at once, but no proposal reached the Senate at its recent meeting; the others not till the Institute is in full working-order. Every encouragement will be given to students properly qualified to pursue research in agricultural matters, and it is hoped that in the future a constant stream of graduates who have received training in the fundamental sciences will be attracted by these scholarships and fellowships, and that from them will eventually be supplied expert teachers in agricultural subjects. It is important to notice that the Institute is quite independent of Government control.

Some time during the year I noted a suggestion, made either in Parliament or in the Press, that all topographical features that have at present Austrian or German names should have these names changed. To me, and I suppose to most other scientific men and intelligent men generally, this appears to be not only a ridiculous proposal but one that is highly undesirable. The names of many mountains in the Alps and those of some of the glaciers would thus be altered, and, if this were done, books of travel in New Zealand, of mountain-climbing, maps, and other documents, would in the future be unintelligible. The Franz-Josef Glacier, for instance, is mentioned in books on geography and geology for certain peculiar features, and to alter its name on the ground that at present we are at war with Austria would render all such references meaningless. If there is any proposal of the kind on foot I think that this Institute should enter a strong protest against it, and obtain the support not only of the affiliated societies, but of associations of all kinds, such as the University colleges, professors, the Alpine Club, tourists, &c.

In my last address I referred to the need of taking steps to protect the interesting rock shelters in Otago and Canterbury on the walls of which are paintings executed by the early inhabitants of New Zealand. I suggested that a committee should be set up, but I do not know that anything further was done. I understand that the matter is to be brought forward at the meeting of the Board of Science and Art; but it seems to me distinctly the province of this Institute to persuade the Government to take some action to protect these interesting records.

* Note by Hon. Secretary.—No intimation has been received.

There remain one or two suggestions that have occurred to me in regard to the annual volume. One is that the report of our annual meeting should be published as soon as possible after it has been held. In the case of the affiliated societies the report of their annual meeting is issued to members very shortly after that meeting, but in the case of the meeting of the Governors it is, as you are aware, delayed till the volume of *Transactions* is issued, and it happened that this year I did not see the volume till early in January. I do not see why the report should not be published (with a separate paging, if necessary in roman numerals) within a month of our meeting, and circulated to every member of the Institute. I believe more interest would be taken in this meeting if this were done. At present the pagination of this report is continuous with that of the scientific transactions, but if roman numerals were used for this report and all that succeeds it in the volume there would be no difficulty in binding up this report with the rest of the volume.

Why should the proceedings of the various societies be printed in the volume at all? Nowadays they consist almost wholly of a list of the new members elected at each meeting, with the title of the addresses delivered or papers read. Formerly some epitome was given of what took place at these meetings, and that had its interest; but the present bare record can have no interest for any one. It is true that an abstract of the annual report is given, and this is the only part of the Proceedings that has any interest whatever to members of the Institute at large.

Professor Kirk at the last meeting gave a notice of motion allowing the Board of Governors some discretion in this direction, and I hope he will move this motion to-day.

I would suggest that the Publication Committee consider these two matters.

A third matter has occurred to me—viz., whether the Treasurer of the New Zealand Institute examines the balance-sheets of the affiliated societies and ascertains whether they comply with the regulations under the Act of 1903—as to the number of members, and the subscription annually paid towards the promotion of art, science, or other branch of knowledge; and as to the expenditure in support of a library or museum.

At our last meeting it was resolved to urge the Government to take immediate steps to form a scientific and technological library. Has anything been done in this direction? No mention of the need of such a library occurs in the report of the Committee on scientific and industrial research, yet surely before any work of value can be carried out it is necessary that the researchers should have access to what has already been done.

By "library" I do not mean a building; but there ought to be undertaken the making and printing of a catalogue of all books on science and technology—and the latter should perhaps be listed first—which are in the various Government Departments, in the General Assembly library, in all University colleges, the Institutes, and Museums. No such comprehensive catalogue exists here as there is, for instance, in Victoria. Though it is true that a printed catalogue soon gets out of date, yet it does serve a very useful purpose, and additional leaflets could be added annually. For we must not overlook the fact that many, perhaps most, of the problems that may present themselves to the manufacturers in the Dominion, such as the utilization of by-products, the improvement in methods of manufacture, and so forth, have already been met in other parts of the world as a result of research: there is a store of scientific knowledge which is no doubt unknown to most of our industrialists, but which would be of great service to them, for it is only in a few cases that the problems are of such a peculiar character in New Zealand that special research is needed.

I trust, therefore, that the Institute will take steps to carry into effect that resolution at an early date.

It seems to me that at our annual meeting many resolutions are proposed and carried which are mere pious resolutions, such as are supposed to be made on New Year's Day, and nothing comes of them.

WELLINGTON PHILOSOPHICAL SOCIETY.

EIGHT general meetings of the society (including the annual meeting) were held during the year 1917, at which the following papers and addresses were read:—(25th April) "Fly and Mosquito Larvicides," by Professor H. B. Kirk; "Perpetual Calendars," by Professor D. M. Y. Sommerville: (23rd May) "Proportional Representation—a New Zealand Experience," by the President, Mr. G. Hogben: (27th June) "The Development of Hydro-electric Power in Canterbury," by Mr. L. Birks: (25th July) "The Outline of New Zealand," by Dr. C. A. Cotton; "An Experiment in the Teaching of Fundamental Ideas in Geometry," by Miss P. Myers: (22nd August) "Hydro-electric Development of Power in Tasmania," by Mr. H. D. Cook: (26th September) "Crystal Analysis by means of X Rays," by Professor H. Clark: (24th October) "Further Notes on New Zealand Bird-song," by Mr. J. C. Andersen; "The Botanical Districts of New Zealand," by Dr. L. Cockayne; "Notes on New Zealand Floristic Botany," by Dr. L. Cockayne: (12th December) "Descriptions of New Zealand Lepidoptera," by Mr. E. Meyrick (communicated by Mr. G. V. Hudson); "Is Earth-rotation the Cause of the Ocean Currents," by Mr. A. W. Burrell (communicated by Dr. C. E. Adams); "A Note on the Young of *Astraea heliotropium* (Martyn)," by Miss M. K. Mestayer (communicated by Mr. R. L. Mestayer); "The Star Test for Telescopic Mirrors," by Mr. T. Allison (communicated by Dr. C. E. Adams); "Comparisons between the Tidal Predictions and Actuality at the Ports of Auckland and Wellington," by Dr. C. E. Adams; "Harmonic Analysis of Tidal Observations," by Dr. C. E. Adams; "Prediction of Tides," by Dr. C. E. Adams; "Notes on East Coast Earthquakes, 1914–1917," by Mr. G. Hogben; "Physiography and Agriculture of the Coastal District of Western Wellington," by Mr. A. H. Cockayne and Dr. C. A. Cotton; "Evidence of Warping on the Eastern Side of the Port Nicholson Depression," by Dr. C. A. Cotton; "The Physiography of Rough Ridge, Otago," by Dr. C. A. Cotton.

At the annual general meeting (24th October) the annual report and balance-sheet were adopted.

ABSTRACT OF ANNUAL REPORT.

New Zealand Standard or Mean Time.—The Council forwarded to the Government a report drawn up by a committee giving reasons why New Zealand mean time should be altered so as to be exactly twelve hours in advance of Greenwich civil mean time. The Government replied that on account of the war it could not see its way to take any action at present. Printed copies of the report have been distributed to the other affiliated societies and to other bodies interested, and the matter will not be lost sight of.

The proposal originated in a resolution passed by the Council on the 30th November, 1916, following the reading of a paper on "Daylight-saving" before the society by Mr. C. W. Adams. The reform was also supported by the National Efficiency Board.

Grant for Research.—Advice was received from the New Zealand Institute that a portion of the £250 voted by Parliament for research had not been applied for, and applications for grants therefrom were invited. On the recommendation of the Council, grants in aid of out-of-pocket expenses were made in the following cases: (1) £50 to Messrs. W. S. La Trobe and C. E. Adams for a tide-predicting machine, and (2) £25 to Professor H. B. Kirk for an investigation of methods of killing mosquitoes and larvae.

Science and Industry Committee.—On the 26th July, 1916, a committee was appointed by the society to report on the organization of scientific and industrial research and the study of science within New Zealand.

The committee held twelve meetings, and its final report was adopted by the society at its September meeting, and was forwarded to the New Zealand Institute for consideration. The report will be printed at the end of a parliamentary paper dealing with the question of the relation between science and industry throughout the Empire.

Tide-gauges at Outlying Islands of New Zealand.—The Council urged on the Government the importance of establishing tide-gauges at the outlying islands of New Zealand, in order that further investigations of the tides of the Pacific might be made. The Government has deferred consideration of the matter until after the war.

Proposed Reform of the New Zealand Institute.—The New Zealand Institute having forwarded Dr. Thomson's proposals for the reform of the Institute, a report by the Council on these proposals was sent to the other incorporated societies, and replies fully discussing it have been received from the Philosophical Institute of Canterbury, the Otago Institute, the Auckland Institute, and the Manawatu Philosophical Society.

Technical Library.—The Council endorsed a resolution of the Science and Industry Committee urging the importance of a technical library, and forwarded the resolution to the New Zealand Institute for transmission to the Government for its favourable consideration and action.

Journal of Science.—A proposal made by the Minister of Internal Affairs for the establishment of a Journal of Science was considered, and the following resolution was adopted and endorsed by the Council: "The Technological Section of the Wellington Philosophical Society is of opinion that the publication of a Dominion Journal of Science, open to contributions from all sources, is a necessity and satisfies a long-felt want, and hereby offers its heartiest congratulations to the Minister of Internal Affairs upon his action in founding and establishing the Journal, but respectfully suggests that the title be altered to read, 'The New Zealand Journal of Science and Technology,' thereby extending the scope of the Journal." The Minister has agreed to the change of title.

Hamilton Memorial.—The report of the Hamilton Memorial Committee has been received (see pp. 333–34).

Jubilee of the Society.—The 13th November, 1917, is the fiftieth anniversary of the foundation of the society. The Council considers that owing to the present state of war it is not desirable to take any steps to celebrate the jubilee this year.

Membership.—Since the annual meeting of 1916 twelve members have been elected, one member has become a life member under Rule 26, one life member (Mr. R. Coupland Harding) and one ordinary member have died, while one member has been killed in action. Six members have resigned their membership. The roll now stands at nine life members, twenty-three members on active service or in camp in New Zealand, and 146 ordinary members, making a total of 178 members.

The following officers and Council were elected for the year 1918: *President*—G. Hogben, C.M.G., M.A., F.G.S. *Vice-Presidents*—R. W. Holmes, M.Inst.C.E.; C. E. Adams, D.Sc., F.R.A.S. *Council*—C. A. Cotton, D.Sc., F.G.S.; T. H. Easterfield, M.A., Ph.D.; F. W. Furkert, A.M.Inst.C.E.; C. Monro Hector, M.D., B.Sc., F.R.A.S.; J. Henderson, M.A., D.Sc., B.Sc. (Eng.); S. H. Jenkinson; H. B. Kirk, M.A.; W. S. La Trobe, M.A.; E. Parry, B.Sc., M.I.E.E., A.M.Inst.C.E.; D. M. Y. Sommerville, M.A., D.Sc., F.R.S.E. *Secretary and Treasurer*—J. Allan Thomson, M.A., D.Sc., F.G.S. *Auditor*—E. R. Dymock, F.I.A.N.Z. *Representatives on the New Zealand Institute*—G. Hogben, C.M.G., M.A., F.G.S.; H. B. Kirk, M.A.

ASTRONOMICAL SECTION.

The following papers have been read before the section during the year 1917:—(4th October) "Long-period Variables," by C. E. Adams, D.Sc.: (1st November) "The Hartness Turret Telescope," by C. E. Adams, D.Sc.; "An Easy Method of Night Marching by the Stars," by G. Hogben, F.G.S.: (6th June) Presidential Address, "The Importance of Pure Science," by W. S. La Trobe, M.A.; "Description of a Planisphere," by D. M. Y. Sommerville, M.A.; "Comet a 1917 Mellish," by C. E. Adams, D.Sc.: (4th July) "An Appreciation of the Early Astronomers," by the Rev. B. Dudley, F.R.A.S.; "A Homogram for Transit Star Factors," by C. E. Adams, D.Sc.: (4th August) "The Principle of Relativity," by D. M. Y. Sommerville, M.A.: (5th September) "The Nebulae," by A. C. Gifford, M.A., F.R.A.S.

Committee and Officers for 1918.—Chairman.—D. M. Y. Sommerville, M.A., D.Sc. *Vice-Chairmen* — W. S. La Trobe, M.A.; E. Parry, B.Sc., M.I.E.E., A.M.Inst.C.E. *Committee*—C. P. Powles; H. Clark, M.S., Ph.D.; A. C. Gifford, M.A., F.R.A.S.; C. Monro Hector, M.D., B.Sc., F.R.A.S.; G. S. Hooper. *Director and Curator of Instruments* — C. E. Adams, D.Sc., F.R.A.S. *Hon. Treasurer*—C. P. Powles. *Hon. Secretary*—C. G. G. Berry.

TECHNOLOGICAL SECTION.

The following papers have been read during 1917:—(9th May) "Irrigation in New Zealand," by F. W. Furkert, A.M.Inst.C.E.: (13th June) "Smelting of Ironsand at Onehunga," by J. M. Chambers (communicated by E. Parry); "Experiments on the Smelting of Ironsand," by J. E. L. Cull, B.Sc.: (11th July) "Losses through Evaporation and Percolation from Irrigation-works," by F. W. Furkert, A.M.Inst.C.E.; "Diagrams collating Tables of Safe Loads on Stanchions," by W. S. La Trobe, M.A.; "Friction of Water in Pipes," by E. Parry, B.Sc.: (8th August) "Convenient Diagrams for the Design of Reinforced-concrete Beams," by W. S. La Trobe, M.A.: (12th September) "Datum Levels," by Dr. C. E. Adams; "Economic Aspects of the Greensands of New Zealand," by Dr. J. A. Thomson: (10th October) "Corrosion by Mine-water," by Professor Easterfield; "Crystal Analysis by means of X Rays," by Professor H. Clark; "Failure of High-tension Insulators," by E. Parry, B.Sc.; "Some Torque Diagrams," by S. H. Jenkinson.

The officers for the year 1918 were elected as follows: *Chairman*—S. H. Jenkinson. *Vice-Chairmen*—E. Parry, B.Sc.: W. S. La Trobe, M.A. *Committee*—R. W. Holmes, M.Inst.C.E.; Dr. Maclaurin; H. Sladden, Member of Board of Surveyors; Professor H. Clark; F. W. Furkert, A.M.Inst.C.E. *Secretary*—A. J. Patterson.

GEOLOGICAL SECTION.

The following papers have been read during 1917: C. A. Cotton, "Across America by the Santa Fe Route," and "The Age and Correlation of the Covering Strata in Central and Eastern Otago"; J. A. Thomson, "The So-called Drift Formation of Hawera," "The Relative Age of the North Otago and South Canterbury Limestones," and "The Geology of the Clarence Valley between the Bluff and the Herring River"; P. G. Morgan, "Potash in New Zealand"; J. Henderson, "The Physiography of that Part of the Waikato Valley near Maungatautari," and "The Geology of the Waitomo Caves"; J. A. Bartrum, "Some Concretions in Recent Sediments in Auckland Harbour"; W. Donovan, "Some Analysis of New Zealand Coals"; E. K. Lomas, "The Teaching of Geography."

The section is indebted to these members for their work, and for thus maintaining the interest in the Geological Section.

At the conclusion of Mr. Lomas's paper on "The Teaching of Geography" the following motion was carried: "That the Council be requested to urge upon the Government the importance both from the educational and economic standpoint of the more extensive publication of the meteorological observations for a larger number of stations in New Zealand."

Officers and Committee for 1918.—Chairman—J. Henderson, M.A., D.Sc. *Vice-Chairman*—E. K. Lomas, M.A., M.Sc. *Committee*—G. Hogben, C.M.G., M.A., F.G.S.; R. W. Holmes, M.Inst.C.E.; P. G. Morgan, M.A., F.G.S.; J. A. Thomson, M.A., D.Sc., F.G.S.; G. Uttley, M.A., M.Sc., F.G.S. *Hon. Secretary*—C. A. Cotton, D.Sc., F.G.S.

AUCKLAND INSTITUTE.

Seven meetings were held during the year 1917, at which the following lectures and papers were read:—(11th June) "Berlin, Bagdad, and the Balkans—Germany's Eastern Ambitions," by Professor J. P. Grossmann: (9th July) "The Kermadec Islands, their Plant and Bird Life," by Mr. W. R. B. Oliver: (6th August) "Some Present Aspects of the War," by the Rev. W. G. Monckton: (3rd September) "Natural Sources of Power, their Importance to New Zealand," by Mr. F. E. Powell, C.E.: (1st October) "Heredity," by Professor A. P. W. Thomas, F.L.S.: (19th November) "The Civic Spirit of Roman Architecture," by Mr. T. G. Price: (11th December) "A New Species of *Hypolepis*," by Mr. H. Carse; "The Extraordinary Rainfall of 1915–1916," by Mr. H. B. Devereux; "On the Distribution of the Pentatonic Scale in Britain," by Professor J. C. Johnson; "On the Sporophyte of *Rhipogonum scandens*," by Miss A. C. Tizard (communicated by Professor J. C. Johnson); "Descriptions of New Native Flowering-plants," by Mr. D. Petrie.

At the annual meeting (25th February, 1918) the annual report and audited financial statement was read to the meeting, and ordered to be printed and distributed among the members.

Abstract.

The report which the Council now presents to the members marks the completion of the fiftieth year of the existence of the society. At the conclusion of such a period it is natural that the governing body, while paying full attention to the requirements of the present, should also concern itself with the demands of the future; or, in other words, take into consideration the subsequent aims and development of the Institute and Museum. The first part of the report will therefore contain the customary account of the activities of the society during the past year, while in the second will be given a brief statement of those views regarding future development that have been discussed at various meetings of the Council, and also the final conclusions that have been arrived at.

Members.—Mainly through a special canvass undertaken by the Hon. E. Mitchelson and another member of the Council, no less than eighty-eight new members have been elected during the year. On the other hand, twenty-nine names have been withdrawn—fourteen from death, ten from resignation, and five from non-payment of subscription for more than two consecutive years. The net gain is thus fifty-nine, the number on the roll at the present time being 450.

Finance.—Full information respecting the financial position of the society is given in the balance-sheets appended to the report; but the following brief synopsis may be useful. The total revenue of the Working Account, after deducting the balance in hand at the beginning of the year, has been £1,827 16s. 7d. This compares favourably with the amount for the previous year, which was £1,741 12s. 6d., showing an increase of £86 4s. 1d. Examining the various items, it will be seen that the members' subscriptions have yielded £420, being an advance of £46 4s. on last year's figures. The receipts from the Museum Endowment, consisting of rents and interest, have amounted to £713 12s. 11d., evidencing a slight decrease. On the other hand, the receipts from the invested funds of the Costley Bequest, which have yielded £453 18s. 1d., are slightly larger than last year's amount. The remaining items call for no special remark. The expenditure has amounted to £1,763 11s. 4d.

Proposals suggesting a reform of the New Zealand Institute were submitted for the consideration of the Council by the Wellington Philosophical Society. The most important of these involved changes in the membership of the Institute which, if carried out in their original shape, would have injuriously affected most of the incorporated societies. The proposals were considered at the recent meeting of the Board of Governors in Wellington, and it is now regarded as probable that most of the objectionable features will be eliminated.

The committee appointed by the Council to consider the co-ordination of science and industry, whose first report appeared last year, has continued its labours during the present session, and has prepared a second communication. This, together with reports from other committees set up by the various branches of the New Zealand Institute, has been placed before a general committee of the Institute sitting in Wellington, which, it is understood, will shortly forward a full statement of its views to the Government.

Museum.—With the exception of a short period necessarily devoted to cleaning and rearrangement, the Museum has been open to the public daily throughout the year. The attendance has been excellent, although not quite equal to that of the three years 1914 to 1916, the total number of visitors being 87,350.

Considerable progress has been made in the Museum during the year. The numerous recent additions to the Maori collections have rendered it necessary to rearrange a large part of the contents of the Maori Hall. The work is not yet completed, but sufficient has been done to make the collections much more intelligible to visitors, and more readily inspected. A plate-glass show-case has been provided for the fine series of taiahas, battle-axes, &c., in the possession of the Museum. These are now much more worthily exhibited, and the space they formerly occupied has supplied accommodation for other articles.

As detailed in last year's report, the completion of the new mineral-room, and the transfer to it of many specimens formerly exhibited in the gallery of the main hall, will provide some additional space for the representation of the New Zealand fauna. It is intended to utilize the table-cases on the south side of the gallery for the reception of the New Zealand shells, and a considerable amount of preliminary work has been done, such as the cleaning and repainting of the cases, the preparation of the trays and tablets for the specimens, cataloguing, sorting, &c. It is hoped to commence the actual arrangement in a short time. In the taxidermist's department Mr. Griffin has nearly completed a very realistic group illustrating the breeding-habits of the black-fronted tern, one of the most graceful of New Zealand birds. The group, which has cost a large amount of patient work and preparation, is of an entirely different character to those already exhibited, and will be generally admired.

The additions and donations received during the year have been numerous and valuable, as will be seen from the list appended to the report, but only the more important can be mentioned here. In the ethnographical department special reference should be made to three historical bone meres, purchased and presented to the Museum by the Hon. A. M. Myers, Mr. Henry Brett, and Mr. R. H. Abbott. Two of these were formerly the property of the celebrated chieftain Rewi Maniapoto, whose name will always be remembered in connection with the Maori War and the defence of Orakau against our troops. The third belonged to the well-known Urewera warrior Hauwai.

Mr. H. E. Partridge has donated ten plaster bas-reliefs of the busts of Maoris and Hawaiians, modelled from life by the well-known sculptor Allan Hutchinson. These will be most useful to the Museum when attempts are made to prepare modelled groups of Maoris engaged in their old-time avocations.

Another valuable addition consists of ten limestone slabs bearing pre-Maori rock-paintings or pictographs, obtained by Dr. Elmore, an American scientist, from certain rock shelters in North Otago. The cost of excavating the slabs, together with others intended for the Otago Museum, was borne by the Otago and Auckland Institutes. Although these pictographs, together with others in Canterbury, have been known for many years, they have not attracted the notice that they certainly deserve.

Single articles of note consist of a remarkably fine and delicately carved charm, or *mauri*, presented by Mr. F. R. Hutchinson; a large and beautifully polished stone adze, contributed by Mr. R. W. Duder; and one of the rare neck-ornaments carved from the teeth of the sperm-whale, donated by Mr. Percy Monk.

In last year's report the Council stated that arrangements had been made with the Gizeh Museum, Cairo, for a first instalment of Egyptian antiquities. The collection has since arrived, and has been placed in a special show-case. It contains about a hundred examples, the most interesting being a series of vases, bowls, libation-vessels, &c., discovered by Dr. Quibell in an 11th dynasty tomb at Sakkarah, near Memphis. The collection forms a very welcome acquisition, and it is hoped that arrangements may be made for other consignments.

Mr. Henry Shaw, whose previous gifts of Japanese porcelain, bronzes, ivories, &c., are still fresh in the memory of the Institute, has made an additional presentation of Satsuma and Kioto porcelain, comprising more than fifty articles, together with a few temporarily lent. A special case has been provided, in which the specimens are now exhibited. The thanks of the Museum have been voted to Mr. Shaw for this renewed instance of liberality.

Dr. C. J. Wood, Bishop of Melanesia, has presented a remarkably good outrigger canoe, 29 ft. in length, from the Island of Tikopia, in the eastern part of the Solomon Group. Dr. Wood had previously contributed two fine canoes of different types to the Museum, and his present gift is valuable as a help towards forming a comparative series.

In the natural-history department, although a considerable number of small additions have been received, no collections of any size have been added, apart from those obtained by the staff of the Museum. It is quite evident that in the future, so far as many classes of specimens are concerned, the Museum must rely on the activities of its own officers, or on trained collectors engaged by it.

Library.—The undoubted risk of loss through submarines, and the greatly increased charges for freight, insurance, &c., have compelled the Council to suspend the purchase of books for the present. It has been decided, however, to keep up the subscriptions to all magazines and serial publications at present on the society's list.

The Council has pleasure in acknowledging the donation by Mr. R. Logan of a copy of Rothschild's costly and magnificent work on "Extinct Birds."

Development of the Museum and the Need for a New Site.—The summary just given of the work performed by the Institute during the year affords many evidences of progress and many proofs of the increasing interest taken by the citizens in both the Museum and library. But regularly increasing donations and additions, however gratifying they may be as proofs of public confidence and support, are every year increasing the difficulty is housing the collections and exhibiting them to the public. They accentuate the one main fact hindering the development of the Museum and the efforts of its guardians to place it on a higher level—want of room. And this want is not confined to one branch of the Museum, but exists in every department. In addition, it effectually prevents any expansion of the present aims of the institution. There are many activities usually associated with a well-ordered and progressive Museum that are excluded from the Auckland Museum through want of room.

Much consideration has been given to the matter by the Council, and several meetings have been held. It soon became obvious that the question for decision was simply this: Can sufficient accommodation, with due regard to future needs, be obtained on the present site; and, if not, what site is best adapted for the purpose? Investigation soon proved that the unbuilt-upon portion of the existing site, with its almost precipitous slope, was likely to prove both inconvenient and expensive, while it was not large enough for present requirements, to say nothing of future needs.

Having arrived at the conclusion that the removal of the Museum from its present position was inevitable, it became necessary for the Council to search for a new locality. In doing this, it was recognized that the new Museum should occupy a central position, and should possess the fundamental advantages of room for future expansion, decreased risk of fire, and freedom from dust and smoke. Further, it was admitted that, as no public Museum in Australia or New Zealand has had to provide its own site, there was no reason why the Auckland Museum should be treated in a different manner.

After an examination of those sites—by no means numerous—that complied with the conditions mentioned above, a meeting of the Council was held to decide which was the most suitable. After full discussion, and after the reasons in favour of changing the site had again been reviewed, the following resolution was moved by the Hon. E. Mitchelson, seconded by Mr. C. J. Parr, M.P., and unanimously adopted: "That this Council is of opinion that the most suitable site upon which to erect a permanent Museum is that part of the Auckland Domain known as Observatory Hill; and that the Auckland City Council be requested to assent to this proposition, with the view of asking Parliament for authority and power to carry out the project."

This expression of the views of the Institute was placed before the City Council at a meeting held on the 7th February. It was supported by the Mayor and Deputy Mayor, who respectively proposed and seconded the following resolution, which was unanimously adopted: "That the request of the Council of the Auckland Institute and Museum for the permission of the Auckland City Council to place a Museum building upon Observatory Hill, in the Auckland Domain, be granted, subject to the Council of the Institute promoting the necessary validating legislation. Further, the Council of the Institute to make provision for the City Council being represented on their body as follows: Mayor of Auckland *ex officio* member of the Council of the Institute, and two others to be nominated by the Auckland City Council." It is a satisfaction to the Council of the Institute to receive such a sympathetic assurance of co-operation from the City Council, and it is hoped that such friendly relations may long exist.

The Council of the Institute has approved of the terms prescribed by the City Council, and is taking steps to promote the necessary legislation as soon as practicable in order to enable the proposed new building to be erected within the Auckland Domain.

Election of Officers for 1918.—President—Mr. J. H. Gunson, Mayor of Auckland. *Vice-Presidents*—Hon. E. Mitchelson; Mr. C. J. Parr, C.M.G., M.P. *Council*—Professor C. W. Egerton, Mr. J. Kenderdine, Mr. T. W. Leys, Mr. E. V. Miller, Mr. T. Peacock, Mr. D. Petrie, Professor H. W. Segar, Professor A. P. W. Thomas, Mr. J. H. Upton, Mr. H. E. Vaile, Professor F. P. Worley. *Trustees*—Mr. T. Peacock, Mr. J. Reid, Professor A. P. W. Thomas, Mr. J. H. Upton, Mr. H. E. Vaile. *Secretary and Curator*—Mr. T. F. Cheeseman. *Auditor*—Mr. S. Gray.

PHILOSOPHICAL INSTITUTE OF CANTERBURY.

During the year 1917 nine meetings were held (including the annual general meeting, 5th December), and the following addresses and papers were presented:—(2nd May) "Some Questions of Efficiency," presidential address, by Mr. L. Birks (discussed, 6th June): (1st August) "The Fly Nuisance and its Control," by Professor H. B. Kirk: (5th September) "Notes on the Susceptibility of New Zealand Timbers to the Attacks of the Borer," by Mr. R. Speight: "On the Conformity of the Amuri and Weka Pass Limestones," by Messrs. R. Speight and L. J. Wild; "A Fossil Isopod belonging to the Fresh-water Genus *Phreatoicus*," by Dr. Charles Chilton; "A Collection of Insects from Cass," by Dr. F. W. Hilgendorf: (3rd October) "Science and Economics," by Dr. J. Hight: (7th November) "Note on a Record of an Earthquake obtained from an Artesian Well," by Mr. L. P. Symes; "The Course of Land-values in Canterbury," by Mr. F. R. Callaghan: (21st November) "Some Poison Gases," by Dr. W. P. Evans: (5th December) "Some Glacial and Structural Features of the Hurunui Valley," by Mr. R. Speight; "Revision of the New Zealand Cirripedia," by the late Captain L. S. Jennings; "Studies in the New Zealand Species of the Genus *Lycopodium*: Part III, the Structure of the Prothallus and the Embryo," by the Rev. Dr. J. E. Holloway; "Testing High-tension Insulators," by Mr. L. Birks; "On the Distribution of *Senecio saxifragoides* Hook. f. and its Relation to *Senecio lagopus* Raoul," by Professor A. Wall (communicated by Mr. R. Speight); "Further Observations on Soil-adsorption," by Mr. L. J. Wild.

At the annual meeting the following officers were elected for 1918: *President*—Mr. W. H. Skinner. *Vice-Presidents*—Mr. L. Birks and Dr. C. C. Farr. *Secretary*—Mr. L. P. Symes. *Treasurer*—Dr. Charles Chilton. *Librarian*—Mr. S. Page. *Council*—Dr. F. W. Hilgendorf, Dr. W. H. Symes, Mr. L. J. Wild, Mr. A. D. Dobson, Mr. W. G. Aldridge, and Mr. W. Martin. *Representatives on the Board of Governors of the New Zealand Institute*—Dr. F. W. Hilgendorf and Mr. L. Birks. *Auditor*—Mr. G. E. Way.

ABSTRACT OF ANNUAL REPORT.

Members on Active Service.—The Council desires to record that the following members are now serving in the Empire's Forces: Drs. H. Acland and F. J. Borrie, Messrs. G. E. Archey, J. W. Bird, F. M. Corkill, E. Kidson, C. E. Foweraker, A. Fairbairn, H. T. Ferrar, A. Taylor, G. T. Weston, F. S. Wilding, A. M. Wright, H. Rands, E. F. Stead.

Obituary.—With great regret the Council records the death of Mr. H. P. Murray-Aynsley, a member for very many years; and that Mr. P. S. Nelson, M.Sc., and Mr. G. MacIndoe, B.E., were killed in action.

Co-ordination of Science and Industry.—This matter has received the constant attention of the Council.

In April, by request of the local Commissioner of the National Efficiency Board, members of the Council waited on him and discussed various matters relative to national efficiency. A number of suggestions were made to the Commissioner, and several matters were referred to members of the Institute for report.

Another matter which has engaged the attention of your Council is the proposal made by the Scientific and Industrial Research Committee of the New Zealand Institute, to recommend the establishment of a national Board of Science and Industry. The Council has criticized some features of the scheme and made suggestions with a view to its improvement. Your Council earnestly trusts that this proposal will materialize and that an institution of great national value will result.

Government Research Grant.—The sum of £110 allotted by the New Zealand Institute to members of this Institute was received in March, and part has been paid over to grantees.

Considerable progress has been made in the investigation of the phosphate rocks of Canterbury by Messrs. R. Speight and L. J. Wild. A paper on some of the results of their observations has been read before the Institute.

Certain preliminary work has been done on the other investigations—viz., the deterioration of apples in cold storage, and the electrical prevention of frosting in orchards.

Proposed Reform of the New Zealand Institute.—The Council has given very serious attention to certain proposals which have been received for the remodelling of the New Zealand Institute. The Council, while anxious that the position of the New Zealand Institute, both financial and otherwise, should be strengthened, has deprecated any action which it considers would injure the local societies or destroy the present representative nature of the governing body.

OTAGO INSTITUTE.

During the year eight ordinary meetings of the Institute were held, at which there were read or received eleven papers embodying the results of original research. The titles of these papers, with the names of the authors, are as follows:—(12th June) "On a Partially White Form of *Puffinus griseus*," by Mr. D. L. Poppelwell; "Notes on a Botanical Visit to Hollyford Valley and Martin's Bay," by Messrs. D. L. Poppelwell and W. A. Thomson; "Notes on a Botanical Excursion to Bunker's Island," by Mr. D. L. Poppelwell; "Notes on a Botanical Visit to Coll or Bench Island," by Mr. D. L. Poppelwell: (9th October) "On the Age of the Alpine Chain of Western Otago," by Professor J. Park, F.G.S.; "On the Miocene (Oamaru Stone) Coral Reef," by Professor J. Park, F.G.S.; "Descriptions of New Species of Lepidoptera," by Mr. Alfred Philpott (communicated); "On the Structure of *Amphibola crenata*," by Miss W. Farnie, M.A. (communicated); "Notes on a Trematode from *Amphibola crenata*," by Miss W. Farnie, M.A. (communicated); "Notes on the Autecology of certain Plants of the Mineral Belt, Nelson," by Miss M. W. Betts, M.Sc. (communicated); "The Origin of Serpentine," by Dr. W. N. Benson, F.G.S.

The following addresses have also been delivered during the past session: "The Position of Science in our Educational System" (presidential address), by Dr. J. K. H. Inglis; "The Coming of the Earthworm to New Zealand," by Dr. W. B. Benham; "The Rainbow Top," by Mr. T. B. Hamilton; "William James and Pragmatism," by Dr. F. W. Dunlop; "The Gyroscope and its Applications," by Dr. R. Jack; "The Occurrence and Genesis of Ore Deposits," by Professor J. Park; and "A Chapter in Evolution," by Dr. W. P. Gowland.

At the annual meeting (4th December) the annual report was adopted, and the following officers were elected for 1918: *President*—Professor R. Jack. *Vice-Presidents*—Professor J. K. H. Inglis and Mr. G. M. Thomson. *Hon. Secretary*—Mr. E. J. Parr. *Hon. Treasurer*—Mr. H. Brasch. *Hon. Auditor*—Mr. J. W. Milnes. *Council*—Professors W. B. Benham, W. N. Benson, J. Park, and D. B. Waters, Dr. R. V. Fulton, Messrs. G. W. Howes and H. Mandeno. *Representatives on the Board of Governors of the New Zealand Institute*—Messrs. G. M. Thomson and E. J. Parr.

Abstract of Annual Report.

The attention of the Council during the year has been very largely centred upon the consideration of a proposal for the reform of the New Zealand Institute. The proposed scheme of reform, which originated in the first instance with the Director of the Dominion Museum, has been submitted by the New Zealand Institute to each of the affiliated societies for its careful consideration. At the present time it appears that when the scheme comes up for final consideration by the New Zealand Institute at its annual meeting in January it will be considerably restricted in its scope before its final adoption. As regards some of the more important features of the scheme, your Council has expressed itself as being in favour of the proposed appointment or election of Fellows of the Institute as a mark of distinction in recognition of scientific research work, and also of the proposal to hold public meetings of the New Zealand Institute in various centres in rotation, and is strongly of the opinion that an increased Government grant is urgently needed by the Institute in order that it may carry on its work. It does not, however, see any necessity for altering the constitution of the Board of Governors of the Institute, nor for the establishment of an associate membership.

At the request of the New Zealand Institute your Council has also co-operated with the other affiliated societies in drawing up recommendations and suggestions to assist the Efficiency Board in drafting a scheme for the co-ordination of science and industry.

Support was also given to the Wellington Philosophical Society in its endeavour to have New Zealand mean time made exactly twelve hours in advance of Greenwich mean time, instead of eleven hours and a half as at present.

A sum of five guineas has been donated to the Sir William Ramsay Memorial Fund, which is to be used for improvements in the training of chemists for industrial work.

TECHNOLOGICAL BRANCH.

Five meetings were held during 1917, and the following papers and addresses were read: (22nd May) "Steam Generators," by Mr. R. A. McLintock; (19th June) "Fuels for Internal-combustion Engines," by Mr. J. B. Mason; (17th July) "Bridge-design on the New Zealand Railways," by Mr. F. J. Jones; (21st August) "The Fire Hazard of Electrical Installations," by Mr. F. R. Shepherd; (16th October) "Hydro-electrical Power," by Mr. M. C. Henderson.

At the meeting of the 16th October the annual report of the branch was read and adopted, and the following officers for 1918 were elected: *Chairman*—Mr. J. B. Mason. *Vice-Chairmen*—Professors J. Park and D. B. Waters, and Mr. B. B. Hooper. *Hon. Secretary*—Mr. H. Brasch. *Committee*—Messrs. M. C. Henderson, F. J. Jones, H. Mandeno, G. Simpson, and R. N. Vanes.

ASTRONOMICAL BRANCH.

Only one meeting was held during the year—that of the 23rd October; a paper on "Astronomy in War-time" was read by Mr. J. W. Milnes.

The following officers for 1918 were elected at the same meeting: *Chairman*—Mr. R. Gilkison. *Vice-Chairmen*—Professors R. Jack, J. Park, and D. R. White. *Hon. Secretary*—Mr. J. W. Milnes. *Committee*—Dr. P. D. Cameron, and Messrs. H. Brasch, C. Frys, W. T. Neill, E. J. Parr, and W. S. Wilson.

HAWKE'S BAY PHILOSOPHICAL INSTITUTE.

Eight meetings were held during 1917, and the following papers were read: (18th May) "Old Hawke's Bay—the Provincial Days," by W. Dinwiddie; (18th June) "The Marvels of Luminiferous Ether," by J. W. Poynton, S.M.; (27th July) "The Development of Thought and Language, chiefly in regard to the Lower Animals," by T. Hyde; (17th August) "Bacon and Shakespeare," by H. Hill, B.A., F.G.S.; (28th September) "Popular Bacteriology," by J. W. Poynton, S.M.; (2nd November) "History and Development of the Water-supply of the Taupo Plains," by H. Hill, B.A., F.G.S.; (13th December) "Milk as a Food," by E. G. Loten.

At the annual meeting (13th December) the annual report was read and adopted, and the following officers for 1918 were elected: *President*—T. Hyde. *Vice-President*—W. A. Armour, M.A., M.Sc. *Council*—W. Dinwiddie; H. Hill, B.A., F.G.S.; F. Hutchinson, jun.; W. Kerr, M.A.; E. G. Loten; T. C. Moore, M.D. *Hon. Secretary and Treasurer*—D. A. Strachan, M.A. *Hon. Auditor*—H. Hill, B.A., F.G.S. *Hon. Lanternist*—E. G. Loten. *Representative*—H. Hill, B.A., F.G S.

MANAWATU PHILOSOPHICAL SOCIETY.

During the year eight general meetings were held, at which the following papers were read: "The Frozen-meat Industry," by M. A. Eliott; "Pairing Relations of Matter in Animal and Vegetable Life," by D. Sinclair, C.E.; "Time, how it is found and kept," by C. T. Salmon, Assoc. in Eng., Canterbury College; "Bird-life in the Southern Islets of New Zealand," by G. Thomas; "Antarctic Exploration," by H. Hill, B.A., F.G.S.; "Economic Plants that should be imported into New Zealand," by J. W. Poynton, S.M.; "Some Unconsidered Aspects of the War," by J. W. Poynton, S.M.; "Hydro-electricity," by A. J. Colquhoun, M.Sc.

At the annual meeting the annual report and balance-sheet was adopted.

Abstract of Annual Report.

During the year several matters not merely of local but of great general importance have occupied the attention of the Council. At their request the Government has agreed to extend the measures for the preservation of native birds to the outlying islets of Stewart Island, and has referred the matter to Dr. Thomson and Mr. Phillips Turner for suggestions as to the measures necessary to be taken, and these gentlemen have issued a full report on the bird-life of the Dominion, a copy of which has been made for our library and is accessible to any member of the society. The Council has also given its warm support to the endeavour of Foxton to secure the preservation of the only piece of native bush remaining in its neighbourhood. We have been officially advised that this object has been attained.

Besides the above, three questions of great importance have been before the Council, and been considered in detail by sub-committees and reported on to the different bodies more immediately concerned:—

(1.) The alteration of the New Zealand mean time from eleven and a half to exactly twelve hours in advance of Greenwich, which would result in a daily saving of half an hour's sunlight, and bring the Dominion into line with the international agreement. This alteration was suggested by the Wellington Philosophical Society, and its consideration has been postponed by the Government on account of the war.

(2.) A scheme for the better co-ordination of scientific work in the Dominion, brought forward by Mr. W. Ferguson, the Chairman of the Efficiency Board, and Dr. Thomson; together with the comments thereon made by the different branches of the Institute in Auckland, Wellington, Canterbury, and Otago. A lengthy and detailed report on these proposals was made by the Council and forwarded to the Secretary of the New Zealand Institute for consideration at the annual meeting in January.

(3.) Proposals for the reorganization of the New Zealand Institute, initiated by Dr. Thomson, with a view to making it as a whole, apart from its branches, an active and efficient scientific body. These also were considered in detail with the comments of the various branches, and suggestions forwarded to the Secretary.

In connection with bird-preservation the Council desires gratefully to acknowledge the aid given by Mr. W. H. Field, M.P., who took the keenest interest in the matter, and personally interviewed the Premier on the subject.

During the year valuable additions to the Museum and the library have been received, including among other items a collection of fifty butterflies and moths from the Dominion Museum, contributed by Dr. Thomson; a collection of minerals from the volcanic region of Rotorua, by Mr. D. Sinclair; and valuable books of reference, by the Ven. Archdeacon Comins (late of Melanesia).

For the first time this year the society has been called upon to contribute £6 15s 6d. towards the general expenses of the New Zealand Institute. As the chief item in these expenses is the publication of the *Transactions*, your Council has included in its suggestions for the reorganization of the New Zealand Institute the proposal that the *Transactions* should be issued gratuitously only to those members who make a written application for the same.

At the annual meeting the following officers for 1918 were elected: *President*—A. J. Colquhoun, M.Sc.. *Vice-Presidents*—C. T. Salmon, Assoc. in Eng.; D. Sinclair, C.E. *Officer in Charge of the Observatory*—A. J. Colquhoun. *Council*—Miss Ironside, M.A.; Messrs. H. Akers, J. L. Barnicoat, C. N. Clausen, M. A. Eliott, R. Gardner, A. Hannay, W. Park, J. Bainforth, J. E. Vernon, M.A.; Dr. W. R. Stowe. *Secretary and Treasurer*—K. Wilson, M.A. *Auditor*—W. E. Bendall, F.P.A.N.Z.

WANGANUI PHILOSOPHICAL SOCIETY.

Eight meetings were held during the session 1917, and various papers and exhibits submitted. The following were the principal papers contributed: "The Tropical Islands of the Eastern Pacific," by Dr. P. Marshall; "Nebulae and Star Clusters," by Mr. J. T. Ward; "History as a Factor in Education," by Mr. H. E. Sturge, M.A.; "The Discovery of America," by Mr. Thomas Allison; "New Zealand Provincialisms in the Use of English," Mr. J. A. Neame, M.A.; "Records of Observations of Mr. A. W. Burrell, of Stratford, suggesting Comparatively Recent Volcanic Activity of Mount Egmont," contributed through Mr. J. T. Ward; "Mendelism," by Dr.

F. W. Hilgendorf; "*Tuna* and *Pa-tuna*—Eels and Eel-weirs," by Mr. T. W. Downes. The last mentioned, and two technical geological papers by Dr. Marshall, were taken as read.

An interesting event of the session was the presentation to Dr. P. Marshall, the President of the Society, of the Hutton Memorial Medal for the year 1917. The medal was awarded for researches in New Zealand geology. The presentation was made by His Excellency the Governor-General, at a public meeting on the 20th September, 1917, on the occasion of his visit to Wanganui to lay the foundation-stone of the Sargeant Art Gallery.

Officers of the Society.—*President*—Dr. P. Marshall, F.R.G.S. *Vice-Presidents*—Mr. J. A. Neame, M.A., and Mr. J. T. Ward. *Council* (including Mr. H. Drew, *ex officio* as Hon. Curator of the Museum)—Messrs. T. Allison; C. Palmer Brown, M.A., LL.B.; R. Murdoch; T. W. Downes; H. E. Sturge, M.A.; H. R. Hatherly, M.R.C.S. *Hon. Treasurer*—Mr. F. P. Talboys. *Hon. Secretary*—Mr. J. P. Williamson. *Representative*—Dr. Marshall.

APPENDIX

NEW ZEALAND INSTITUTE ACT, 1908.

For the New Zealand Institute Act, 1908, and Regulations thereunder see vol. 49, 1917, pp. 570–74.

THE HUTTON MEMORIAL MEDAL AND RESEARCH FUND.

Declaration of Trust.

This deed, made the fifteenth day of February, one thousand nine hundred and nine (1909), between the New Zealand Institute of the one part, and the Public Trustee of the other part: Whereas the New Zealand Institute is possessed of a fund consisting now of the sum of five hundred and fifty-five pounds one shilling (£555 1s.), held for the purposes of the Hutton Memorial Medal and Research Fund on the terms of the rules and regulations made by the Governors of the said Institute, a copy whereof is hereto annexed: And whereas the said money has been transferred to the Public Trustee for the purposes of investment, and the Public Trustee now holds the same for such purposes, and it is expedient to declare the trusts upon which the same is held by the Public Trustee:

Now this deed witnesseth that the Public Trustee shall hold the said moneys and all other moneys which shall be handed to him by the said Governors for the same purposes upon trust from time to time to invest the same upon such securities as are lawful for the Public Trustee to invest on, and to hold the principal and income thereof for the purposes set out in the said rules hereto attached.

And it is hereby declared that it shall be lawful for the Public Trustee to pay all or any of the said moneys, both principal and interest, to the Treasurer of the said New Zealand Institute upon being directed so to do by a resolution of the Governors of the said Institute, and a letter signed by the Secretary of the said Institute enclosing a copy of such resolution certified by him and by the President as correct shall be sufficient evidence to the Public Trustee of the due passing of such resolution: And upon receipt of such letter and copy the receipt of the Treasurer for the time being of the said Institute shall be a sufficient discharge to the Public Trustee: And in no case shall the Public Trustee be concerned to inquire into the administration of the said moneys by the Governors of the said Institute.

As witness the seals of the said parties hereto, the day and year hereinbefore written.

Resolutions of Board of Governors.

Resolved by the Board of Governors of the New Zealand Institute that—

1. The funds placed in the hands of the Board by the committee of subscribers to the Hutton Memorial Fund be called "The Hutton Memorial Research Fund," in memory of the late Captain Frederick

Wollaston Hutton, F.R.S. Such fund shall consist of the moneys subscribed and granted for the purpose of the Hutton Memorial, and all other funds which may be given or granted for the same purpose.

2. The funds shall be vested in the Institute. The Board of Governors of the Institute shall have the control of the said moneys, and may invest the same upon any securities proper for trust-moneys.

3. A sum not exceeding £100 shall be expended in procuring a bronze medal to be known as "The Hutton Memorial Medal."

4. The fund, or such part thereof as shall not be used as aforesaid, shall be invested in such securities as aforesaid as may be approved of by the Board of Governors, and the interest arising from such investment shall be used for the furtherance of the objects of the fund.

5. The Hutton Memorial Medal shall be awarded from time to time by the Board of Governors, in accordance with these regulations, to persons who have made some noticeable contribution in connection with the zoology, botany, or geology of New Zealand.

6. The Board shall make regulations setting out the manner in which the funds shall be administered. Such regulations shall conform to the terms of the trust.

7. The Board of Governors may, in the manner prescribed in the regulations, make grants from time to time from the accrued interest to persons or committees who require assistance in prosecuting researches in the zoology, botany, or geology of New Zealand.

8. There shall be published annually in the "Transactions of the New Zealand Institute" the regulations adopted by the Board as aforesaid, a list of the recipients of the Hutton Memorial Medal, a list of the persons to whom grants have been made during the previous year, and also, where possible, an abstract of researches made by them.

Regulations under which the Hutton Memorial Medal shall be awarded and the Research Fund administered.

1. Unless in exceptional circumstances, the Hutton Memorial Medal shall be awarded not oftener than once in every three years; and in no case shall any medal be awarded unless, in the opinion of the Board, some contribution really deserving of the honour has been made.

2. The medal shall not be awarded for any research published previous to the 31st December, 1906.

3. The research for which the medal is awarded must have a distinct bearing on New Zealand zoology, botany, or geology.

4. The medal shall be awarded only to those who have received the greater part of their education in New Zealand or who have resided in New Zealand for not less than ten years.

5. Whenever possible, the medal shall be presented in some public manner.

6. The Board of Governors may, at an annual meeting, make grants from the accrued interest of the fund to any person, society, or committee for the encouragement of research in New Zealand zoology, botany, or geology.

7. Applications for such grants shall be made to the Board before the 30th September.

8. In making such grants the Board of Governors shall give preference to such persons as are defined in regulation 4.

9. The recipients of such grants shall report to the Board before the 31st December in the year following, showing in a general way how the grant has been expended and what progress has been made with the research.

10. The results of researches aided by grants from the fund shall, where possible, be published in New Zealand.

11. The Board of Governors may from time to time amend or alter the regulations, such amendments or alterations being in all cases in conformity with resolutions 1 to 4.

Award of the Hutton Memorial Medal.

1911. Professor W. B. Benham, D.Sc., F.R.S., University of Otago—For researches in New Zealand zoology.

1914. Dr. L. Cockayne, F.L.S., F.R.S.—For researches on the ecology of New Zealand plants.

1917. Professor P. Marshall, M.A., D.Sc.—For researches in New Zealand geology.

HECTOR MEMORIAL RESEARCH FUND.

Declaration of Trust.

This deed, made the thirty-first day of July, one thousand nine hundred and fourteen, between the New Zealand Institute, a body corporate duly incorporated by the New Zealand Institute Act, 1908, of the one part, and the Public Trustee of the other part: Whereas by a declaration of trust dated the twenty-seventh day of January, one thousand nine hundred and twelve, after reciting that the New Zealand Institute was possessed of a fund consisting of the sum of £1,045 10s. 2d., held for the purposes of the Hector Memorial Research Fund on the terms of the rules and regulations therein mentioned, which said moneys had been handed to the Public Trustee for investment, it was declared (*inter alia*) that the Public Trustee should hold the said moneys and all other moneys which should be handed to him by the said Governors of the Institute for the same purpose upon trust from time to time, to invest the same in the common fund of the Public Trust Office, and to hold the principal and income thereof for the purposes set out in the said rules and regulations in the said deed set forth: And whereas the said rules and regulations have been amended by the Governors of the New Zealand Institute, and as amended are hereinafter set forth: And whereas it is expedient to declare that the said moneys are held by the Public Trustee upon the trusts declared by the said deed of trust and for the purposes set forth in the said rules and regulations as amended as aforesaid:

Now this deed witnesseth and it is hereby declared that the Public Trustee shall hold the said moneys and all other moneys which shall be

handed to him by the said Governors for the same purpose upon trust from time to time to invest the same in the common fund of the Public Trust Office, and to hold the principal and income thereof for the purposes set out in the said rules and regulations hereinafter set forth:

And it is hereby declared that it shall be lawful for the Public Trustee to pay, and he shall pay, all or any of the said moneys, both principal and interest, to the Treasurer of the said New Zealand Institute upon being directed to do so by a resolution of the Governors of the said Institute, and a letter signed by the Secretary of the said Institute enclosing a copy of such resolution certified by him and by the President as correct shall be sufficient evidence to the Public Trustee of the due passing of such resolution: And upon receipt of such letter and copy the receipt of the Treasurer for the time being of the said Institute shall be a sufficient discharge to the Public Trustee: And in no case shall the Public Trustee be concerned to inquire into the administration of the said moneys by the Governors of the said Institute.

As witness the seals of the said parties hereto, the day and year first hereinbefore written.

Rules and Regulations made by the Governors of the New Zealand Institute in relation to the Hector Memorial Research Fund.

1. The funds placed in the hands of the Board by the Wellington Hector Memorial Committee be called "The Hector Memorial Research Fund," in memory of the late Sir James Hector, K.C.M.G., F.R.S. The object of such fund shall be the encouragement of scientific research in New Zealand, and such fund shall consist of the moneys subscribed and granted for the purpose of the memorial and all other funds which may be given or granted for the same purpose.

2. The funds shall be vested in the Institute. The Board of Governors of the Institute shall have the control of the said moneys, and may invest the same upon any securities proper for trust-moneys.

3. A sum not exceeding one hundred pounds (£100) shall be expended in procuring a bronze medal, to be known as the Hector Memorial Medal.

4. The fund, or such part thereof as shall not be used as aforesaid, shall be invested in such securities as may be approved by the Board of Governors, and the interest arising from such investment shall be used for the furtherance of the objects of the fund by providing thereout a prize for the encouragement of such scientific research in New Zealand of such amount as the Board of Governors shall from time to time determine.

5. The Hector Memorial Medal and Prize shall be awarded annually by the Board of Governors.

6. The prize and medal shall be awarded by rotation for the following subjects, namely—(1) Botany, (2) chemistry, (3) ethnology, (4) geology, (5) physics (including mathematics and astronomy), (6) zoology (including animal physiology).

In each year the medal and prize shall be awarded to that investigator who, working within the Dominion of New Zealand, shall in the opinion of the Board of Governors have done most towards the advancement of that branch of science to which the medal and prize are in such year allotted.

7. Whenever possible the medal shall be presented in some public manner.

AWARD OF THE HECTOR MEMORIAL RESEARCH FUND.

1912. L. Cockayne, Ph.D., F.L.S., F.R.S.—For researches in New Zealand botany.
1913. T. H. Easterfield, M.A., Ph.D.—For researches in chemistry.
1914. Elsdon Best—For researches in New Zealand ethnology.
1915. P. Marshall, M.A., D.Sc., F.G.S.—For researches in New Zealand geology.
1916. Sir Ernest Rutherford, F.R.S.—For researches in physics.
1917. Charles Chilton, M.A., D.Sc., F.L.S., C.M.Z.S. — For researches in zoology.
1918. T. F. Cheeseman, F.L.S., F.Z.S. — For researches in New Zealand systematic botany.

REGULATIONS FOR ADMINISTERING THE GOVERNMENT RESEARCH GRANT.

ALL grants shall be subject to the following conditions, and each grantee shall be duly informed of these conditions :—

1. All instruments, specimens, objects, or materials of permanent value, whether purchased or obtained out of or by means of the grant, or supplied from among those at the disposal of the Institute, are to be regarded, unless the Research Grants Committee decide otherwise, as the property of the Institute, and are to be returned by the grantee, for disposal according to the orders of the committee, at the conclusion of his research, or at such other time as the committee may determine.

2. Every one receiving a grant shall furnish to the Research Grants Committee, on or before the 1st January following upon the allotment of the grant, a report (or, if the object of the grant be not attained, an interim report, to be renewed at the same date in each subsequent year until a final report can be furnished or the committee dispense with further reports) containing (*a*) a brief statement showing the results arrived at or the stage which the inquiry has reached ; (*b*) a general statement of the expenditure incurred, accompanied, as far as is possible, with vouchers; (*c*) a list of the instruments, specimens, objects, or materials purchased or obtained out of the grant, or supplied by the committee, which are at present in his possession ; and (*d*) references to any transactions, journals, or other publications in which results of the research have been printed. In the event of the grantee failing to send in within three months of the said 1st January a report satisfactory to the committee he may be required, on resolution of the Board of Governors, to return the whole of the sum allotted to him.

3. Where a grant is made to two or more persons acting as a committee for the purpose of carrying out some research, one member of the said committee shall assume the responsibility of furnishing the report and receiving and disbursing the money.

4. Papers in which results are published that have been obtained through and furnished by the Government grant should contain an acknowledgment of that fact.

5. Every grantee shall, before any of the grant is paid to him, be required to sign an engagement that he is prepared to carry out the general conditions applicable to all grants, as well as any conditions which may be attached to his particular grant.

6. In cases where specimens or preparations of permanent value are obtained through a grant the committee shall, as far as possible, direct that such specimens shall be deposited in a museum or University college within the province where the specimens or material were obtained, or in which the grantee has worked. The acknowledgment of the receipt of the specimens by such institution shall fully satisfy the claims of the Institute.

7. In cases where, after completion of a research, the committee directs that any instrument or apparatus obtained by means of the grant shall be deposited in an institution of higher learning, such deposit shall be subject to an annual report from the institution in question as to the condition of the instrument or apparatus, and as to the use that has been made of it.

Research Grants from Vote (£500) to 31st March, 1918.

Through the Philosophical Institute of Canterbury:—

- Professor W. P. Evans, £200 for the investigation of New Zealand brown coals; granted 11th March, 1918.
- Professor Charles Chilton, £50 for the investigation of New Zealand flax (phormium); granted 11th March, 1918.

Through the Otago Institute:—

- Professor John Malcolm, £30 for the investigation of New Zealand plant pharmacology; granted 11th March, 1918.

Through the Wellington Philosophical Society:—

- Professor T. H. Easterfield, £50 for investigation of the wax content of New Zealand brown coals; granted 11th March, 1918.

THE CARTER BEQUEST.

For extracts from the will of Charles Rooking Carter see vol. 48, 1916, pp. 565–66.

NEW ZEALAND INSTITUTE

ESTABLISHED UNDER AN ACT OF THE GENERAL ASSEMBLY OF NEW ZEALAND INTITULED THE NEW ZEALAND INSTITUTE ACT, 1867; RECONSTITUTED BY AN ACT OF THE GENERAL ASSEMBLY OF NEW ZEALAND UNDER THE NEW ZEALAND INSTITUTE ACT, 1903, AND CONTINUED BY THE NEW ZEALAND INSTITUTE ACT, 1908.

BOARD OF GOVERNORS.

EX OFFICIO.

His Excellency the Governor-General.
The Hon. the Minister of Internal Affairs.

NOMINATED BY THE GOVERNMENT.

Mr. Charles A. Ewen (reappointed December, 1916); Dr. J. Allan Thomson, F.G.S. (reappointed December, 1917); Mr. B. C. Aston, F.I.C., F.C.S. (reappointed December, 1917); Dr. Charles Chilton, F.L.S., C.M.Z.S. (reappointed December, 1916).

ELECTED BY AFFILIATED SOCIETIES (DECEMBER, 1917).

Wellington Philosophical Society ...	Professor H. B. Kirk, M.A. Mr. George Hogben, M.A., C.M.G.
Auckland Institute	Professor H. W. Segar, M.A. Professor A. P. W. Thomas, M.A.
Philosophical Institute of Canterbury ...	Dr. F. W. Hilgendorf, M.A. Mr. L. Birks, B.Sc.
Otago Institute	Mr. G. M. Thomson, F.C.S., F.L.S. Mr. E. J. Parr, M.A., B.Sc.
Hawke's Bay Philosophical Institute ...	Mr. H. Hill, B.A., F.G.S.
Nelson Institute	Dr. L. Cockayne, F.L.S., F.R.S.
Manawatu Philosophical Society ...	Mr. M. A. Eliott.
Wanganui Philosophical Society ..	Dr. P. Marshall, F.G.S.

OFFICERS FOR THE YEAR 1918.

President: Dr. L. Cockayne, F.R.S.
Hon. Treasurer: Mr. C. A. Ewen.
Hon. Editors: Dr. L. Cockayne, F.R.S.; Dr. C. A. Cotton, F.G.S.
Hon. Librarian: Dr. J. Allan Thomson, F.G.S.
Hon. Secretary: Mr. B. C. Aston, F.I.C., F.C.S.
(Box 40, Post-office, Wellington).

AFFILIATED SOCIETIES.

Name of Society.	Secretary's Name and Address.	Date of Affiliation.
Wellington Philosophical Society	J. Allan Thomson, Dominion Museum, Wellington	10th June, 1868.
Auckland Institute ..	T. F. Cheeseman, Museum, Auckland	10th June, 1868.
Philosophical Institute of Canterbury	L. P. Symes, 22 Mays Road, Christchurch	22nd October, 1868.
Otago Institute	E. J. Parr, Boys' High School, Dunedin	18th October, 1869.
Hawke's Bay Philosophical Institute	C. F. H. Pollock, P.O. Box 166, Napier	31st March, 1875.
Nelson Institute	E. L. Morley, Waimea Street, Nelson	20th December, 1883.
Manawatu Philosophical Society	K. Wilson, 92 Rangitikei Street, Palmerston North	6th January, 1905.
Wanganui Philosophical Society	J. P. Williamson, Box 171, Wanganui	2nd December, 1911.

FORMER HONORARY MEMBERS.

1870.

Agassiz, Professor Louis.
Drury, Captain Byron, R.N.
Finsch, Professor Otto, Ph.D.
Flower, Professor W. H., F.R.S.
Hochstetter, Dr. Ferdinand von.
Hooker, Sir J. D., G.C.S.I., C.B., M.D., F.R.S., O.M.
Mueller, Ferdinand von, M.D., F.R.S. C.M.G.
Owen, Professor Richard, F.R.S.
Richards, Rear-Admiral G. H.

1871.

Darwin, Charles, M.A., F.R.S.
Gray, J. E., Ph.D., F.R.S.
Lindsay, W. Lauder, M.D., F.R.S.E.

1872.

Grey, Sir George, K.C.B.
Huxley, Thomas H., LL.D., F.R.S.
Stokes, Vice-Admiral J. L.

1873.

Bowen, Sir George Ferguson, G.C.M.G.
Günther, A., M.D., M.A., Ph.D., F.R.S.
Lyell, Sir Charles, Bart., D.C.L., F.R.S.
Pickard-Cambridge, Rev. O., M.A., F.R.S., C.M.Z.S.

1874.

McLachlan, Robert, F.L.S.
Newton, Alfred, F.R.S.
Thomson, Professor Wyville, F.R.S.

1875.

Filhol, Dr. H.
Rolleston, Professor G., M.D., F.R.S.
Sclater, P. L., M.A., Ph.D., F.R.S.

1876.

Berggren, Dr. S.
Clarke, Rev. W. B., M.A., F.R.S.
Etheridge, Professor R., F.R.S.

1877.

Baird, Professor Spencer F.
Weld, Frederick A., C.M.G.

1878.

Garrod, Professor A. H., F.R.S.
Müller, Professor Max, F.R.S.
Tenison-Woods, Rev. J. E., F.L.S.

1880.

The Most Noble the Marquis of Normanby, G.C.M.G.

1883.

Carpenter, Dr. W. B., C.B., F.R.S.
Ellery, Robert L. J., F.R.S.
Thomson, Sir William, F.R.S.

1885.

Gray, Professor Asa.
Sharp, Richard Bowdler, M.A., F.R.S.
Wallace, A. R., F.R.S., O.M.

1888.

Beneden, Professor J. P. van.
Ettingshausen, Baron von.
McCoy, Professor F., D.Sc., C.M.G., F.R.S.

1890.

Riley, Professor C. V.

1891.

Davis, J. W., F.G.S., F.L.S.

1895.

Mitten, William, F.R.S.

1896.

Langley, S. P.
Lydekker, Richard, F.R.S.

1900.

Agardh, Dr. J. G.
Avebury, Lord, P.C., F.R.S.
Massee, George, F.L.S., F.R.M.S.

1901.

Eve, H. W., M.A.
Howes, G. B., LL.D., F.R.S.

1906.

Milne, J., F.R.S.

1909.

Darwin, Sir George, F.R.S.

FORMER MANAGER AND EDITOR.

[Under the New Zealand Institute Act, 1867.]

1867–1903.

Hector, Sir James, M.D., K.C.M.G., F.R.S.

PAST PRESIDENTS.

1903–4.

Hutton, Captain Frederick Wollaston, F.R.S.

1905–6.

Hector, Sir James, M.D., K.C.M.G., F.R.S.

1907–8.

Thomson, George Malcolm, F.L.S., F.C.S.

1909–10.

Hamilton, A.

1911–12.

Cheeseman, T. F., F.L.S., F.Z.S.

1913–14.

Chilton, C., M A., D.Sc., LL.D., F.L.S., C.M.Z.S.

1915.

Petrie, D., M.A., Ph.D.

1916–17.

Benham, W. B., M.A., D.Sc., F.Z.S., F.R.S.

HONORARY MEMBERS.

1877.

Sharp, Dr. D., University Museum, Cambridge.

1890.

Liversidge, Professor A., M.A., F.R.S., Fieldhead, Coombe Warren, Kingston Hill, England.

Nordstedt, Professor Otto, Ph.D., University of Lund, Sweden.

1891.

Goodale, Professor G. L., M.D., LL.D., Harvard University, Massachusetts, U.S.A.

1894.

Codrington, Rev. R. H., D.D., Wadhurst Rectory, Sussex, England.

Thiselton-Dyer, Sir W. T., K.C.M.G., C.I.E., LL.D., M.A., F.R.S., Witcombe, Gloucester, England.

1901.

Goebel, Professor Dr. Carl von, University of Munich.

1902.

Sars, Professor G. O., University of Christiania, Norway.

1903.

Klotz, Professor Otto J., 437 Albert Street, Ottawa, Canada.

1904.

Rutherford, Professor Sir E., D.Sc., F.R.S., Nobel Laureate, University of Manchester.

David, Professor T. Edgeworth, F.R.S., C.M.G., Sydney University, N.S.W.

1906.

Beddard, F. E., D.Sc., F.R.S., Zoological Society, London.

Brady, G. S., D.Sc., F.R.S., University of Durham, England.

1907.

Dendy, Dr. A., F.R.S., King's College, University of London, England.

Diels, Professor L., Ph.D., University of Marburg.

Meyrick, E., B.A., F.R.S., Marlborough College, England.

Stebbing, Rev. T. R. R., F.R.S., Tunbridge Wells, England.

1910.

Bruce, Dr. W. S., Edinburgh.

1913.

Davis, Professor W. Morris, Harvard University.

Hemsley, Dr. W. Botting, F.R.S., Strawberry Hill, London, England.

1914.

Arber, Dr. E. Newell, Cambridge, England.

Balfour, Professor I. Bayley, F.R.S., Royal Botanic Gardens, Edinburgh.

Haswell, Professor W. A., F.R.S, University, Sydney.

1915.

Bateson, Professor W., F.R.S., Merton, Surrey, England.

1916.

Massart, Professor Jean, University of Brussels, Belgium.

ORDINARY MEMBERS.

WELLINGTON PHILOSOPHICAL SOCIETY.

[* Life members † On active service.]

Ackland, E. W., P.O. Box 928, Wellington.
Adams, C. E., D.Sc., A.I.A. (London), F.R.A.S., Hector Observatory, Wellington.
Adams. C. W., Bellevue Road, Lower Hutt.*
Adamson, Professor J., M.A., LL.B., Victoria University College, Wellington.
Adkin, G. L., Queen Street, Levin.
Andersen, Johannes C., General Assembly Library, Wellington.
Anderson, W. J., M.A., LL.D., Education Department, Wellington.
Andrew, R. L., Dominion Laboratory, Wellington.
Aston, B.C., F.I.C., F.C.S., P.O. Box 40, Wellington.
Atkins, A., F.R.I.B.A., A.M.Inst.C.E., 9 Grey Street, Wellington.
Atkinson, E. H., Agricultural Department, Wellington.†
Bagley, G., care of Young's Chemical Company, 14 Egmont Street, Wellington.
Baillie, H., Public Library, Wellington.
Bakewell, F. H., M.A., Education Board, Mercer Street, Wellington.
Baldwin, E. S., 215 Lambton Quay, Wellington.
Beetham, W. H., Masterton.
Begg, Dr. C. M., 164 Willis Street, Wellington.†
Bell, E. D., Panama Street, Wellington.
Bell, Hon. Sir Francis H. D., K.C., M.L.C., Panama Street, Wellington.
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Blair, David K., M.I.Mech.E., 9 Grey Street, Wellington.
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Bretherton, A. C., Public Trust Office, Wellington.
Bridges, G. G., 2 Wesley Road, Wellington.
Broadgate, F. L. K., M.Sc., Dominion Museum, Wellington.†
Brodrick, T. N., Under-Secretary, Lands and Survey Department, Wellington.
Brown, J., Experimental Farm, Weraroa.
Browne, M. H., Education Department, Wellington.
Burbidge, P. W., M.Sc., Victoria University College, Wellington.†
Burnett, J., M.Inst.C.E., care of M. Burnett, of Richardson, McCabe, and Co., 11 Grey Street, Wellington.
Burton, Richard F., Longner Hall, Salop, Shrewsbury, England.*
Cameron, Dr. R. A., 148 Willis Street, Wellington.
Campbell, J., F.R.I.B.A., Government Architect, Public Works Department, Wellington.
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Chapman, Martin, K.C., Brandon Street, Wellington.
Chudleigh, E. R., Orongomairoa. Waihou.
Clark, Professor H., Victoria University College, Wellington.
Clarke, J. T., care of Messrs. Searle, Joy, and Co., 61 Victoria Street, Wellington.
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Crawford, A. D., Box 126, G.P.O., Wellington.
Cull, J. E. L., B.Sc. in Eng. (Mech.), Public Works Department, Wellington.
Curtis, H. F., 19 May Street, Wellington.
Darling, J., Kelburn.
Davies, V. C., Devon Street, New Plymouth.†
Donovan, W., M.Sc., Dominion Laboratory, Wellington.
Doré, A. B., Bacteriological Laboratory, Wellington.
Dougall, Archibald, 9 Claremont Grove, Wellington.
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Earnshaw, W., 4 Watson Street, Wellington.†
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Ewen, Charles A., Heretaunga, Upper Hutt.
Ferguson, William, M.A., M. Inst. C. E., M.I.Mech.E., 131 Coromandel Street, Wellington.
Findlay, Sir John G., K.C., LL.D., 197 Lambton Quay, Wellington.
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Fox, Thomas O., Borough Engineer, Miramar, Wellington.
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Furkert, F. W., A.M.Inst.C.E., Public Works Department, Wellington.

Garrow, Professor J. M. E., B.A., LL.B., Victoria University College, Wellington.*
Gavin, W. H., Public Works Department, Wellington.
Gibbs, Dr. H. E., 240 Willis Street, Wellington.
Gifford, A. C., M.A., F.R.A.S., 6 Shannon Street, Wellington.*
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Goudie, H. A., Whakarewarewa.
Gray, W., Mauriceville.
Hamilton, H., A.O.S.M., 58 Bowen Street, Wellington.†
Hanify, H. P., 18 Panama Street, Wellington.
Hansford, George D., Parliamentary Buildings, Wellington.
Hastie, Miss J. A., care of Street and Co., 30 Cornhill, London E.C.*
Hector, C. Monro, M.D., B.Sc., F.R.A.S., Lower Hutt.
Helyer, Miss E., 13 Tonks Grove, Wellington.
Henderson, J., M.A., D.Sc., B.Sc. in Eng. (Metall.), Geological Survey Department, Wellington.
Hislop, J., Internal Affairs Department, Wellington.
Hodson, W. H., 40 Pirie Street, Wellington.
Hogben, G., C.M.G., M.A., F.G.S., 32 Crescent Road, Khandallah.
Holmes, R. L., F.R.Met.Soc., "Kia Ora," Fern Street, Randwick, Sydney.*
Holmes, R. W., M.Inst.C.E., Engineer-in-Chief, Public Works Department, Wellington.
Hooper, Captain G. S., Grant Road, North Wellington.
Hudson, G. V., F.E.S., Inspector's Office, G.P.O., Wellington.
Jack, J. W., 170 Featherston Street, Wellington.
James, L. G., P.O. Box 94 (Hunter Street), Wellington.
Jenkinson, S. H., Railway Department, Wellington.
Johnston, Hon. G. Randall, care of Martin Chapman, K.C., Wellington.*
Jones, E. G., B.A., 33 Ellice Avenue, Wellington.†
Joseph, Joseph, P.O. Box 443, Wellington.
Kempthorne, Mrs. H. E., Bellevue Road, Lower Hutt.
Kennedy, Rev. Dr. D., F.R.A.S., St. Patrick's College, Wellington.
King, G. W., B.E., care of A. H. King, P.O. Box 116, Christchurch.†
Kirk, Professor H. B., M.A., Victoria University College, Wellington.
La Trobe, W. S., M.A., Technical College, Wellington.
Lawton, H. W., Education Board, Wellington.
Levi, P., M.A., care of Wilford and Levi, 15 Stout Street, Wellington.
Lomas, E. K., M.A., M.Sc., Training College, Wellington.
Lomax, Major H. A., Araruhe, Aramoho, Wanganui.
Luke, John P., C.M.G., M.P., Hiropi Street, Wellington.
McCabe, Ultan F., care of Richardson and McCabe, 11 Grey Street, Wellington.
McDonald, J., Dominion Museum, Wellington.
McKenzie, Donald, care of Mrs. Elizabeth McKenzie, Marton.†
Maclaurin, J. S., D.Sc., F.C.S., Dominion Laboratory, Wellington.
MacLean, F. W., M.Inst. C.E., Chief Engineer, Head Office, Railway Department, Wellington.
Marchbanks, J., M.Inst.C.E., Harbour Board, Wellington.
Marsden, Professor E., D.Sc., Victoria University College, Wellington.†
Mason, J. Malcolm, M.D., F.C.S., D.P.H., Lower Hutt.
Maxwell, J. P., M.Inst.C.E., 145 Dixon Street, Wellington.
Mestayer, R. L., M.Inst.C.E., 139 Sydney Street, Wellington.
Millar, H. M., Public Works Department, Wellington.†
Mills, Leonard, New Parliamentary Buildings, Wellington.
Moore, G., Eparaima, via Masterton.
Moore, W. Lancelot, care of H. D. Cook, Bank Chambers, Lambton Quay, Wellington.†
Moorhouse, W. H. Sefton, 134 Dixon Street, Wellington.
Morgan, P. G., M.A., F.G.S., Director of Geological Survey, Routh's Buildings, Wellington.
Morice, J. M., B.Sc., Town Hall, Wellington.
Morison, C. B., Stout Street, Wellington.
Morrison, J. C., P.O. Box 8, Eltham.
Morton, W. H., M.Inst.C.E., City Engineer, Wellington.
Myers, Miss P., B.A., 26 Fitzherbert Terrace, Wellington.
Newman, A. K., M.B., M.R.C.P., M.P., 56 Hobson Street, Wellington.
Nicol, John, 57 Cuba Street, Wellington.
Norris, E. T., M.A., Registrar, University of New Zealand, Wellington.
Ongley, M., M.A., Geological Survey Department, Wellington.†
Orchiston, J., M.I.E.E., 16 Rimu Road, Kelburn.
Orr, Robert, Heke Street, Lower Hutt, Wellington.
Parry, Evan, B.Sc., M.I.E.E., A.M.Inst.C.E., Electrical Engineer, Public Works Department, Wellington.
Paterson, A. J., City Engineer's Office, Town Hall, Wellington.
Patterson, Hugh, Assistant Engineer, Public Works Office, Ngatapa.
Pearce, Arthur E., care of Levin and Co. (Limited), Wellington.
Phillips, Coleman, Carterton.*

Phillipps, W. J., Dominion Museum, Wellington.
Phipson, P. B., F.C.S., care of J. Staples and Co. (Limited), Wellington.
Pierard, A. C., Bacteriological Laboratory, Wellington.
Pigott, Miss Ellen, M.A., Victoria University College, Wellington.
Pomare, Hon. Dr. M., M.P., Wellington.
Porteous, J. S., 9 Brandon Street, Wellington.
Porter, Colonel T. W., 12 Austin Street, Wellington.
Powles, C. P., 219 Lambton Quay, Wellington.
Reakes, C. J., D.V.Sc., M.R.C.V.S., Agricultural Department, Wellington.
Reid, W. S., 189 The Terrace, Wellington.
Richardson, C. E., P.O. Box 863 (11 Grey Street), Wellington.
Roy, R. B., Taita, Wellington.*
Salmond, J. W., K.C., M.A., LL.B., Crown Law Office, Wellington.
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Geological Survey of Western Australia: *Annual Report; Bulletins.*
Museum and Art Gallery, Perth: *Records.*

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Botanical Society of Edinburgh: *Transactions and Proceedings.*
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Liverpool Geological Society: *Proceedings.*
Marine Biological Association: *Journal.*
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Natural History Society of Glasgow: *Glasgow Naturalist.*
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Société Zoologique de France : *Bulletin.*

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Revista Geographica Italiana.
Società Africana d'Italia : *Bollettino.*
Società Toscana di Scienze Naturali, Pisa : *Processi verbali.*

NORWAY.

Bergens Museum : *Aarbok ; Crustacea of Norway ; Aarberetning.*

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Société Entomologique de Russie, Petrograd : *Horae ; Revue.*
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Junta de Ciences Naturals de Barcelona : *Series botanica, zoologica, biologico-oceanica.*

SWEDEN.

Botaniska Notiser, Lund.
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Naturforsch. Gesellschaft, Basel : *Verhandlungen.*
Soc. de Phys. et d'Hist. Nat. de Genève : *Mémoires.*

INDIA AND CEYLON.

Agricultural Department, Calcutta : *Report on Progress of Agriculture.*
Agricultural Research Institute and College, Pusa : *Report.*
Asiatic Society of Bengal : *Journal and Proceedings ; Memoirs.*
Board of Scientific Advice for India : *Annual Report.*
Colombo Museum ; *Spolia Zeylanica.*
Geological Survey of India : *Records ; Memoirs.*

Japan.

Icones plantarum Formosanarum, Taihoku.
Imperial Earthquake Investigation Committee, Tokyo: *Bulletin.*
Imperial University of Tokyo: *Journal of the College of Science.*
Tohoku Imperial University, Sendai: *Science Reports.*

Malay States.

Malay States Government Gazette.

Africa.

South African Association for the Advancement of Science: *South African Journal of Science.*
Transvaal Museum: *Annals.*

Canada.

Department of the Interior: *Publications of the Dominion Observatory.*
Department of Marine and Fisheries, Toronto: *Reports of Meteorological Service; Monthly Record of Meteorological Observations.*
Department of Naval Service: *Annual Report; Tide Tables.*
Mines Department, Geological Survey Branch: *Memoirs; Summary Report; Museum Bulletin.*
Mines Department, Mines Branch: *Bulletins;* other publications.
Nova Scotian Institute of Science: *Proceedings and Transactions.*
Royal Society of Canada: *Proceedings and Transactions.*

United States.

Academy of Natural Sciences, Philadelphia: *Proceedings.*
American Geographical Society, New York: *Geographical Review.*
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American Philosophical Society: *Proceedings.*
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Observatorio do Rio de Janeiro: *Annuario.*

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